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PROTOTYPE AUTOMATED EQUIPMENT TO PERFORM POISING AND BEAT RATE --ETC(U)
SEP 78 C BIRO DAAA21-76-C-0157

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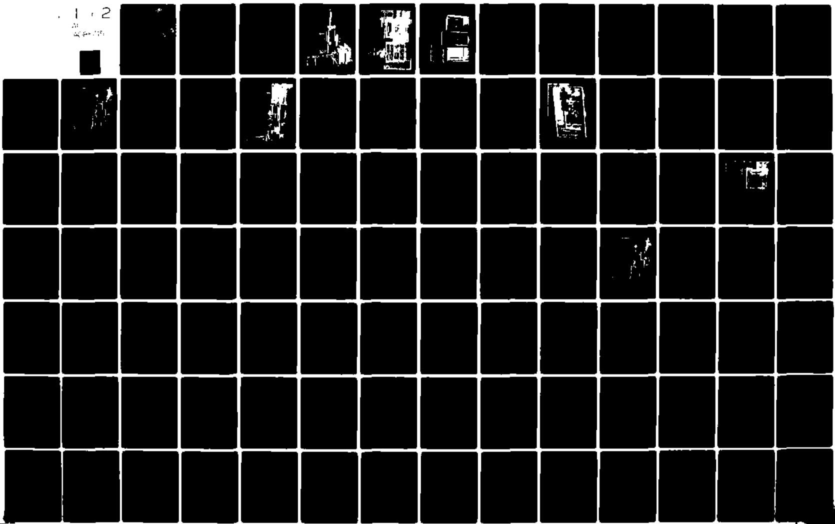

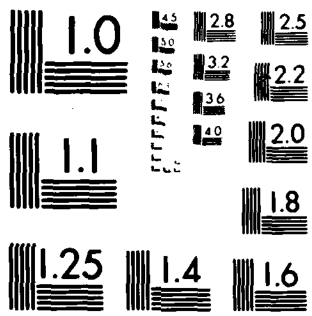

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(6) PROTOTYPE AUTOMATED EQUIPMENT
TO PERFORM
POISING AND BEAT RATE OPERATIONS
ON THE
M577 MTSQ FUZE.

Contract No. DAAA21-76-C-0157 (15)

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1.0 INTRODUCTION

This report summarizes the design and development of two automatic process control machines for the M577 MTSQ Fuze. The work was performed under contract DAAA21-76-C-0157, U.S. ARMY ARRADCOM, DOVER, N.J. from 23 March 1977 through 30 September 1978. This followed an initial feasibility demonstration phase from 4 March 1976 to 4 October 1976.

The two machines developed are the Automatic Regulation Machine which sets the M577 Fuze Timer beat rate and the Automatic Poising Machine which dynamically balances the Timer balance wheel assemblies.

The basic design concepts established during the Engineering Study (Feasibity) Phase provided the primary design parameters for this equipment. The feasibility model of the Automatic Regulation Fixture is shown in Figure 1. Regulation of the Timer Assembly is accomplished by shortening the Hairspring length using successive, progressive ultrasonic welds to the hypodermic tube projecting from the End Support. To regulate in this manner the timer beat frequency established by the initial weld has to be approximately 1.0 beat per second slow. The production Automatic Regulation Machine Figure 2, consists of a manually loaded fixture, a precision servo table, an ultrasonic welder and a Hewlett Packard 9825 computer control. The Timer beat frequency is monitored continuously and the Timer is powered by its Mainspring. Process control data can be printed out at the machine or batched to a central site. Included as auxiliary equipment are an oscilloscope and a visicorder which provide additional process information and aid in trouble shooting.

The Automatic Poising Machine Figure 3 which inspects and corrects the dynamic balance of the Balance Wheel Assembly was developed with the Schenck-Trebel Corp. The machine has two manually loaded interlocked stations. Operation is fully automatic with indicator light to indicate completion of cycle acceptance and rejection. Material removal when required is accomplished by laser beam.

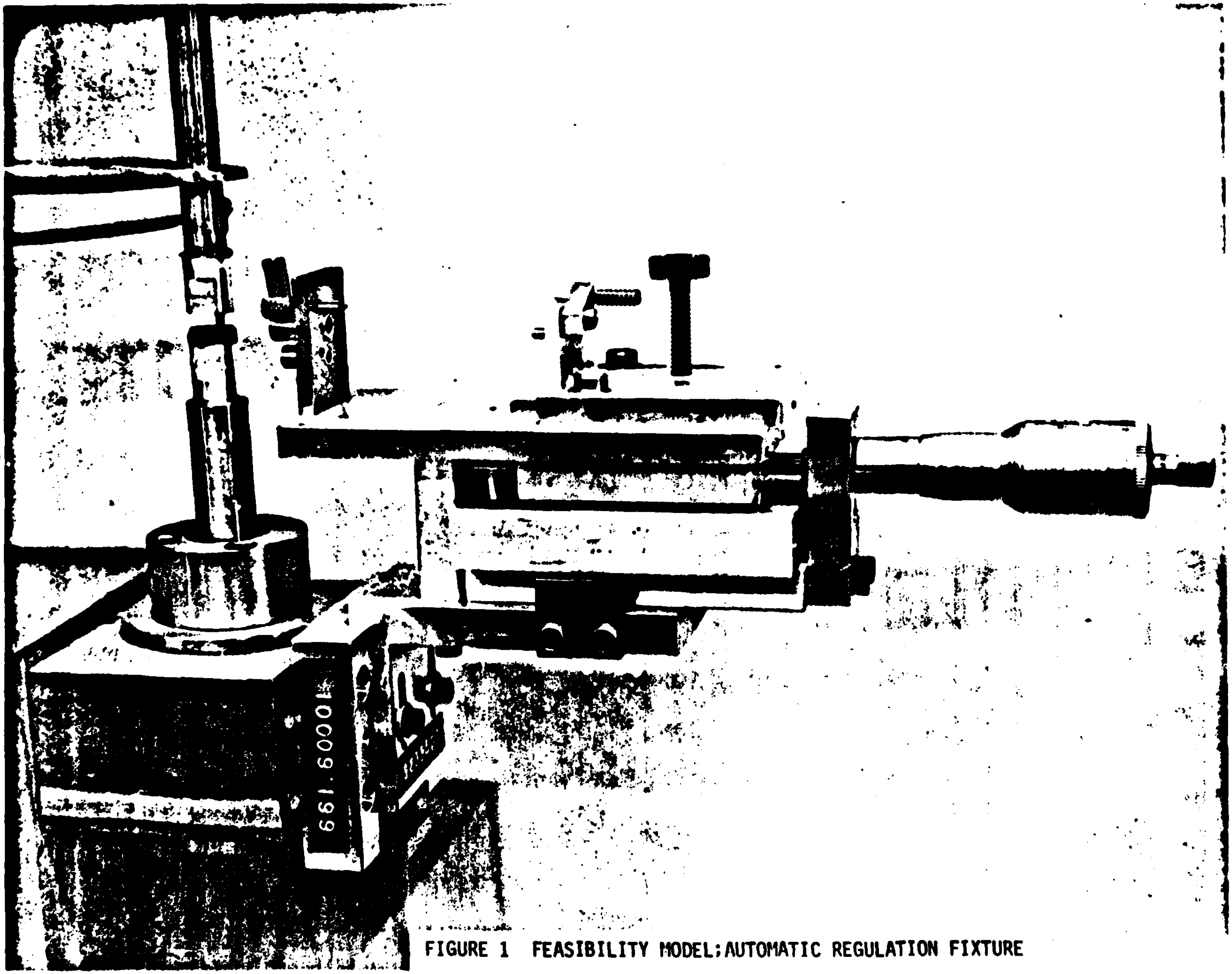


FIGURE 1 FEASIBILITY MODEL; AUTOMATIC REGULATION FIXTURE

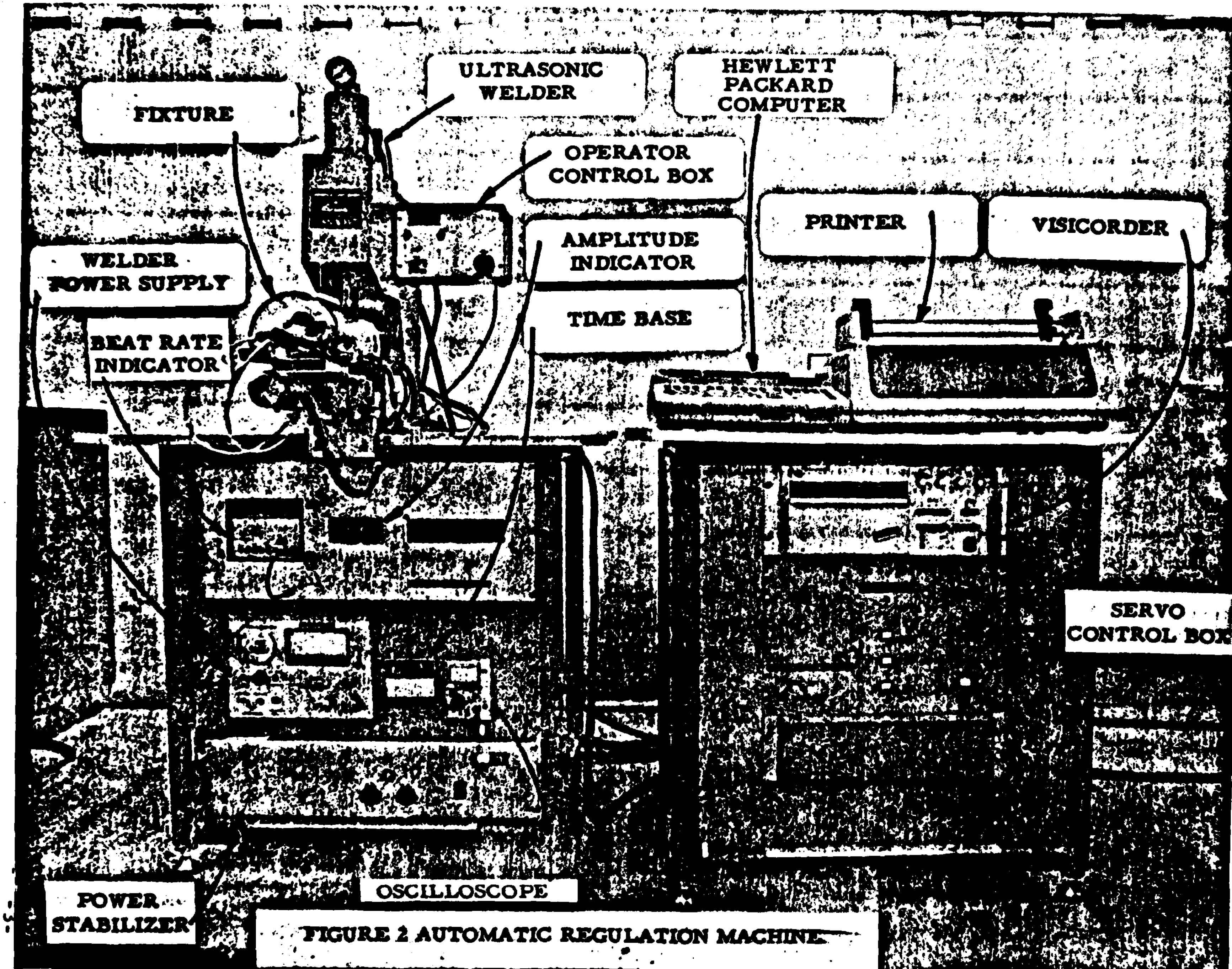


FIGURE 2 AUTOMATIC REGULATION MACHINE

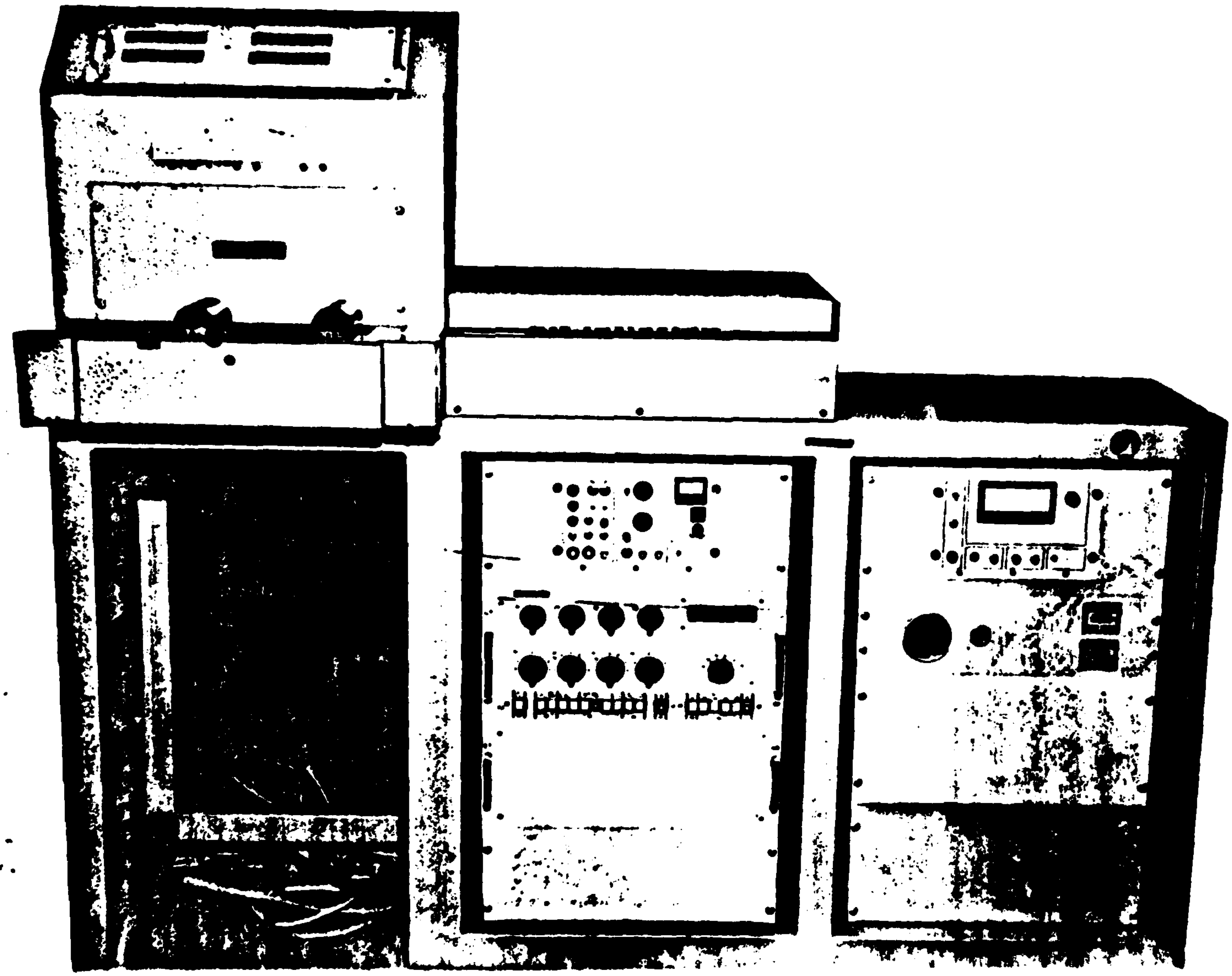


FIGURE 3 AUTOMATIC POISING MACHINE

2.0 AUTOMATIC REGULATION MACHINE

2.1 Background

Since the fundamental operation of this machine is intimately related to the fastening method of the wire to the Timer at one end and the Balance Wheel at the other, a review of the history of this joint may facilitate the discussion.

The prototype M577 Timer, designed in the early 1960's, had a hairspring which was fastened mechanically. The balance end, had a brass bushing which was press-fitted to the end of the .010" diameter balance pivot. One hairspring end was flattened into a spade shape, and was keyed into the brass bushing by being drawn through it. At the other end, the hairspring was held by a split collet, clamped by a set screw, which enabled regulation to be made in either direction. As the fuze design progressed, it was necessary to shrink the regulator diameter to less than 3/16 inch to accommodate a setting mechanism. This was done by designing a spring collet to hold the adjustable end. An attempt to simplify this construction led to a taper pin, screw-adjusted clamp, which was the final prototype configuration. All of the prototype designs required a "trapped plate" subassembly, consisting of the balance assembly and the hairspring assembly press-fitted together with the bushing and pivot as mentioned, with a thin plate between. This prototype subassembly was fragile and difficult to handle. The design solution of this problem, was very closely connected with the development of regulation. The production design eliminated the regulator. The hairspring was fastened directly to the pivot, which was a .018 inch diameter hypodermic tube, at the balance end. The other end was also an .018 inch diameter hypodermic tube, fastened to the hairspring in the same manner. The completed balance-hairspring assembly was much more easily handled than the prototype. The assembly was inserted into the Plate #1 by passing the hypodermic tube, and wire assembly through the Plate #1 bushing, at which time, the outer end was fastened by a split taper collar and epoxyed to the support.

The regulation for this design was accomplished in a fixture. The balance-hairspring assembly, with the outer hypodermic tube not yet assembled to the wire is supported by a micrometer-adjustable clamp on the spring wire and a bearing on the pivot. An adjustable oscillator caused the wheel to vibrate at its natural frequency. An operator adjusted the clamping point until instrumentation showed the rate within tolerance. An integral tool was functioned to cut the spring, which was then fastened to the hypodermic tube at the point at which it had been clamped.

The word "fasten" in the context of the last paragraph, refers to one of three methods. The first production design used a heavy crimp to squeeze the wire inside the tube. The First Article Samples were produced with this method using a "presstaker" tool. Later, epoxy was used to cement the wire in place, necessitating a fine knurl on the wire at the fastening point. In further development, the epoxy was replaced by ultrasonic welding, but the knurl was retained. In the current automatic regulation system, the knurl was eliminated for several reasons. One reason is that the final weld location cannot be predetermined and hence neither can the knurl location. Although, if it was essential, the length of the knurl could be increased. It was found in early destructive pull and torsion test results of the weld joint that unknurled specimens were equivalent to knurled specimens. Firing test results summarized in Section 5; data in Appendix II and IV, show that fuzes with automatically regulated timers containing unknurled hairsprings are equivalent to the production fuzes which contain manually regulated timers with knurled hairsprings. Therefore, the knurl is unnecessary.

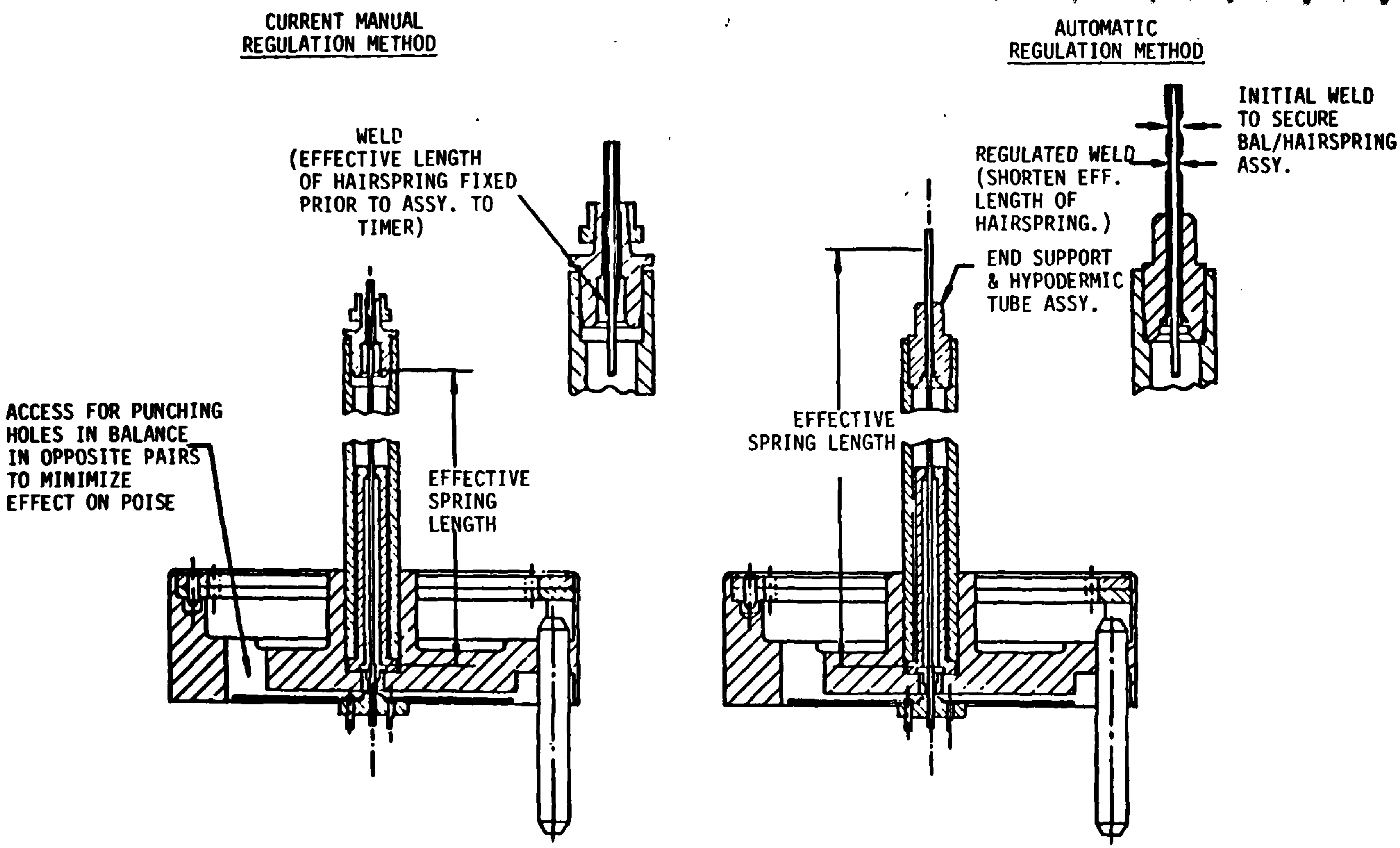
2.2 Principle of Operation

The process of fastening the Hairspring Wire to the supporting structure was changed to ultrasonic welding by NOR 7590034. In this process, the supporting structure is a hypodermic tube, having an inside diameter which has about

.002 inch clearance between itself and the Hairspring Wire. The assembly of wire and tubing is crimped between the Sonotrode and Anvil of an ultrasonic welder, and bonded together. This weld replaced the epoxy cement formerly used to make this joint.

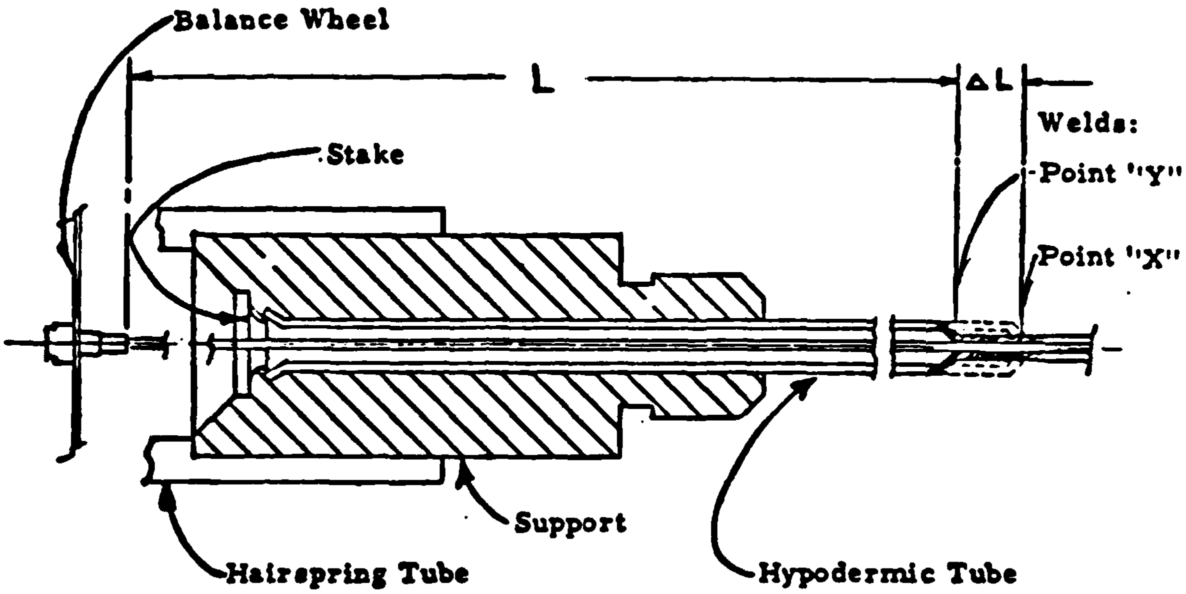
It was decided to take advantage of the speed and controllability of ultrasonic welding and mechanize the regulation process. In the implementation of the process, the configuration of the supporting member to which the hypodermic tube is attached was redesigned. The hypodermic tube was extended outward from the Timer instead of inward, to make it accessible for the subsequent regulating welding operation. Figure 4 shows the manual and automatic methods of regulation.

The principle of automatic regulation is shown on Figure 5. Initially, the Balance Wheel and Hairspring Assembly are welded to the hypodermic tube at point "X". It is done at the subassembly stage of Plate #1 Assembly. The attachment is made in such a way that the "endshake", i.e., the clearance between the Balance Staff thrust shoulder and the Plate #1 Bearing is established, and the "dead beat", i.e., the angular Balance Wheel location is also established. The axial location of the weld location is chosen so as to cause the Timer to run approximately 1 to 1 1/2 beats per second slower than nominal rate. Assembly of the Timer is completed after this operation, the mainspring wound, the Balance Wheel cocked into the starting position and the Setback Pin locked out with the Setback Pin hold-down. The Timer is loaded into the Regulation Machine fixture, and is started. The beat rate and amplitude are measured, and the results automatically read into the computer. The location of point "X", is made a part of the computer program. The difference between the desired, and actual beat rates is computed. An algorithm uses this data to advance the location of the timer a distance of ΔL to point "Y", and a weld is made. The direct result is a shortening of the Hairspring's active length, and consequently, a rise in the beat rate.



M577 FUZE TIMER
MANUAL & AUTOMATIC
REGULATION

FIGURE 4



PRINCIPLE OF AUTOMATIC REGULATION

FIGURE 5

The computer solftware and details of machine operation are included in Appendix I, "INSTRUCTION MANUAL, AUTOMATIC BEAT RATE REGULATION MACHINE"; computer software details in paragraphs 11.0 and 11.1, operation in Paragraph 6.0.

The algorithm for regulation may take different forms. Some examples are as follows:

(a) The incremental regulation advance is illustrated by the "Δ L" dimension on Figure 5. Its value is determined by $\Delta L = K\Delta R$ where ΔR is the difference between final and actual beat rates, and K is a constant, whose value is determined by the Hairspring properties. The value of K for a hairspring diameter of .0085 inches is .036 inches/beat/second. Variations in the wire drawing process, tolerances in diameter, and modulus of elasticity result in a dispersion of regulated beat rates, which may be controlled in different ways. A safety factor may be introduced by a conservative value for K. The number of resulting welds would, on the average, be increased, while the number of "overshoot" Timers would be decreased, until an acceptable trade-off point is achieved. A non-linear safety factor may also be used. An example is of the form $\Delta L = K\Delta R - C\Delta R^E$ where C and E are suitable constants. This algorithm causes the table movement to be more conservative as the amount of regulation increases.

(b) The beat rate may be read before the first weld, or afterward. Figure 6 shows the tack welding arrangement. One method does not require as accurate a "tack" welding location. For example, consider the first bonding of the Hairspring to the Plate #1 Assembly. After assembly and loading into the Regulation Machine, a reference weld is made, following which the beat rate is read. In the alternative method, the beat rate is read first, and associated with the "tack" weld. The incremental move is then made, and the weld cycled.

The former method seems to have the advantage of one fewer weld. Moreover, the "tack" location has not proven to be troublesome to hold. Its location is entered into the algorithm as a conservative value, which may result, infrequently, in an extra weld cycle.

(c) The increment distance may be a constant. This would not be feasible for the entire regulation process, but has been used with some success on "fine tuning", where small table movements are encountered. It shou'd be noted that the ultrasonic welder power is always adjusted to weld a .050 inch wide joint. In the case of a small table increment, the welding power of a .050 inch joint is used to weld a much shorter joint. The result is a greater lateral vibrational sonotrode displacement, with a regulation increment greater than intended.

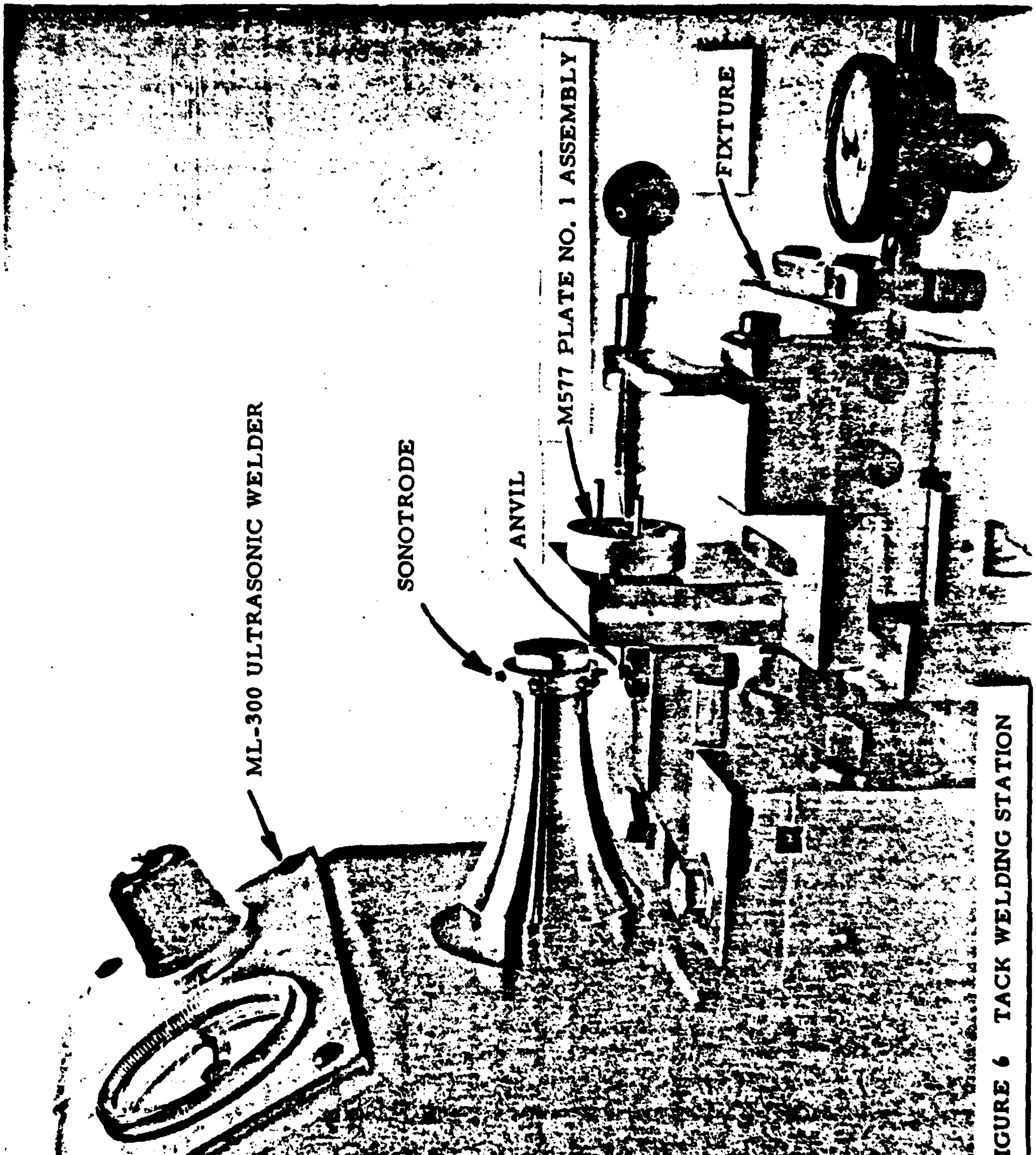


FIGURE 6 TACK WELDING STATION

2.3 MANUALLY-OPERATED PROTOTYPE

Figure 2 shows a prototype fixture used to demonstrate the feasibility of the regulation principle. The weld location is controllable by a micrometer, and the welder cycled by the operator. The operation is performed while the Timer is running under the driving torque of its own mainspring. Standard M577 instrumentation for the detection and readout of the beat rate and the amplitude are in position during the regulation cycle and are used by the operator to determine the setting of the micrometer for each successive weld.

The machine demonstrated that the method was feasible for accomplishing rapid and accurate regulation, and produced Timers which maintained their beat rates during testing.

2.4 HAIRSPRING TACK WELDER

Figure 6 shows the Tack Welder, used to perform the initial weld between the Plate #1 Assembly and the Balance-Hairspring Assembly. The fixture supports the Plate #1 Assembly in the same manner as the Regulation Machine. A shim is used to set the endshake, and a key pin holds the Balance Wheel in the dead-beat position. The welding point location is controlled by a dial indicator, after an initial trial-and-error determination, to result in approximately one to one-and one-half beats per second, slow rate.

It should be noted that the ML-300 welder is illustrated here, while the M600 welder is shown in other illustrations. Either welder can be used for either operation. The ML-300 has the advantage of an indexable multi-typed sonotrode, which lasts longer between sharpenings. The ML-300 anvil also is more easily adjusted, using two cross slides instead of one.

2.5 Fixture, Servo & Sensors

Figure 7 shows the work holding fixture of the Automatic Regulation Machine. The operation of the fixture is described in the section on "Interface" in the Instruction Manual (Appendix I). The Timer is loaded by hand into the fixture, orienting the flat on Plate #1 as noted in the sketch in the Instruction Manual. The machine cover is closed and the cycle initiated.

The computer algorithm contains instructions to check the condition of three proximity switch sensors, as depicted in Figure 7. One of these is activated by closing the protective cover. One is at the base of the Timer, and is activated by the presence of a Timer. If these two sensors are in the correct state, the air cylinder clamps the fixture. This action engages the Scroll pivot into the fixture bearing, clamps the Timer against its stop, and releases the Balance Wheel, starting the Timer. Another sensor is activated by the fixture jaws closing fully. The beat rate and amplitude are then detected with conventional M577 instrumentation. If the amplitude is within limits, the algorithm calculates the table incremental movement required. The table movement is under the control of a servo, which is visible at the lower right hand side of Figure 7. The table location depends upon the servo's master scale, which is calibrated in steps of .0001 inch. There is a preselectable "home" position, which initializes the system once each cycle. After the regulation cycling, described elsewhere in this report, the fixture retracts, the door latch is released by a solenoid, and the cover springs open. The operator then removes the regulated Timer, noting the condition of the ACCEPT or REJECT light.

The proximity sensor used to detect workpiece presence is based upon the eddy current principle and can detect the presence of metal up to 1/16 inches. The other proximity sensors are Hall effect devices. They detect the presence of a small magnetic field at a working distance of 1/16 inch.

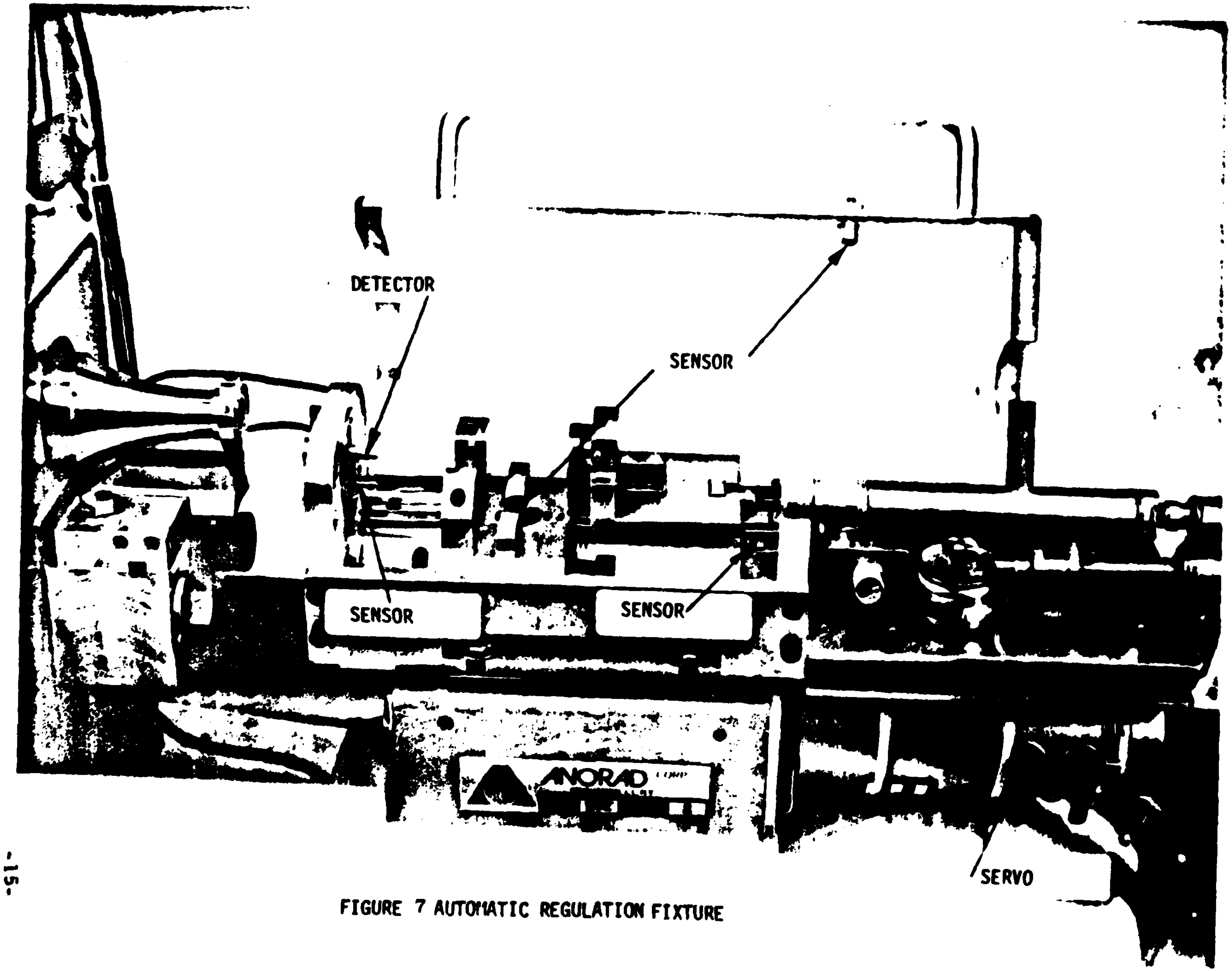


FIGURE 7 AUTOMATIC REGULATION FIXTURE

2.6 Ultrasonic Welder and Sonotrodes

The method used for fastening hairspring wire to hypodermic tubing in the automatic regulation process is similar to the pre-existing method with some changes. The changes are necessitated by different requirements and by options in the welder type.

The tacking and regulation welders perform welding which is not required to pass through a bushing, as is required of both welds in the previous system. The tubing diameter was increased from .018 to .022 and then to .024 in the final phase. Therefore, the anvil shape may be modified to a more efficient shape. A V-shaped anvil and sonotrode, with a greater angle, was chosen for tacking, and yields good results. The V's tend to centralize the wire inside the tube. The opening of the V's are wider than the previous design, permitting a greater lateral dimensional tolerance in the location of the workpiece.

Either the M600 or the ML 300 Sonobond Welder may be used on tacking or regulation operations. The ML 300 permits a multiple-toolhead sonotrode design to be used, which facilitates set-up because of the ease with which a fresh sonotrode may be set. Both units use the identical power supply.

The V anvils are made of RDS steel. The regulation machine anvils have flat faces and are made of tungsten carbide. The carbide anvils are inserts, press-fitted into aluminum holders. The M-600 welder uses individual anvils which are threaded in such a manner as to effect proper angular orientation when the anvil is torqued on, facilitating anvil replacement.

The operational procedures and other matters relating to the set-up operation, maintenance and troubleshooting of the welders are adequately covered by their respective handbooks. In addition, other factors were discovered in the pursuit of the subject programs. For the welding of the hypodermic tube to the

hairspring wire, best results are obtained with the M600 machine, with a high ram speed, giving maximum impact upon the workpiece. It was found that sticking between the carbide anvil and the workpiece sometimes occurred when new anvils were installed. A smear of lubricating oil on the anvils eliminated the problem. As an alternative, it is possible to program the servo table to retract before advancing, without incurring additional processing time. This will break the sticking anvils loose before repositioning. Best results were obtained with a ground (machine) finish of approximately 32 microinches RMS on the carbide anvil work surfaces, with the grinding direction perpendicular to the workpiece axis.

2.7 Computer and Software

The Hewlett Packard 9825 Computer was selected from among many candidate computers for several reasons.

(a) It is sensor-oriented. The Hewlett Packard Company makes many scientific instruments, all of which are easily interfaced with the 9825 in a manner similar to the present requirements.

(b) It is readily programmable by anyone familiar with BASIC language.

(c) It is capable of being operated in a time-sharing mode. At the time these decisions were made, this seemed important. At the present time, it is considered more cost-effective to have separate computers for each welding station, since the cost of a single day's downtime exceeds the cost of one computer.

(d) The size of the memory and the ease with which either continuous data, or randomly selected data concerning production may be obtained, is similar to a large computer. The memory size may be very readily increased with the addition of tape or disc modules. Thus, production control, quality control and troubleshooting procedures are greatly facilitated.

(e) The Hewlett Packard Company is large and reputable and is likely to support their products, and design changes should be evolutionary; old and new equipment will be compatible.

(f) The Bulova Systems & Instruments Corporation has had much favorable experience with the Hewlett Packard Company and confidence in their products, therefore, is high.

3.0 AUTOMATIC POISING MACHINE

The assembly of the Balance Wheel and Pivot, including the Staff Impulse and Guard Pin, requires that it be balanced with respect to the mass central coincidence with the geometric center. If the out-of-poise condition exceeds an established value, eccentric projectile motion can cause an inertia torque to appear on the Balance Wheel, whose magnitude may be great enough to affect the Timer's performance.

The value for the maximum permissible out-of-balance condition was experimentally determined to be .001 inch (center of mass of the balance) multiplied by 0.1 grams (balance mass). In conventional balance units this would be expressed as 250 microgram cemtimeters.

At present, the assembly is checked by a sampling of production. A unit is tested for balance by permitting oscillation to take place while it is supported on a knife-edged poising tool. The minimum time which it takes to displace a given angle is the acceptance criterion. This method is very slow and its accuracy is affected by air movement, specks of dirt and operator judgement.

On the basis of an open set-up, whereby a YAG laser was used to remove material to balance M577 Balance Wheels under the control of a Schenck balancing machine, a feasibility study was made, and a balancing machine was ordered from this company.

Figure 3 shows the Automatic Poising Machine. The laser power control panel is at the right. In the center, at the top, is the laser firing control panel. Below it is the trigger control panel. This determines the width, frequency and location of the laser beam pattern, electronically. For example, the laser beam is adjusted not to remove material at the spokes, or to cut air between tabs. At the upper left are the two work stations and a display panel. The panel has a LED readout

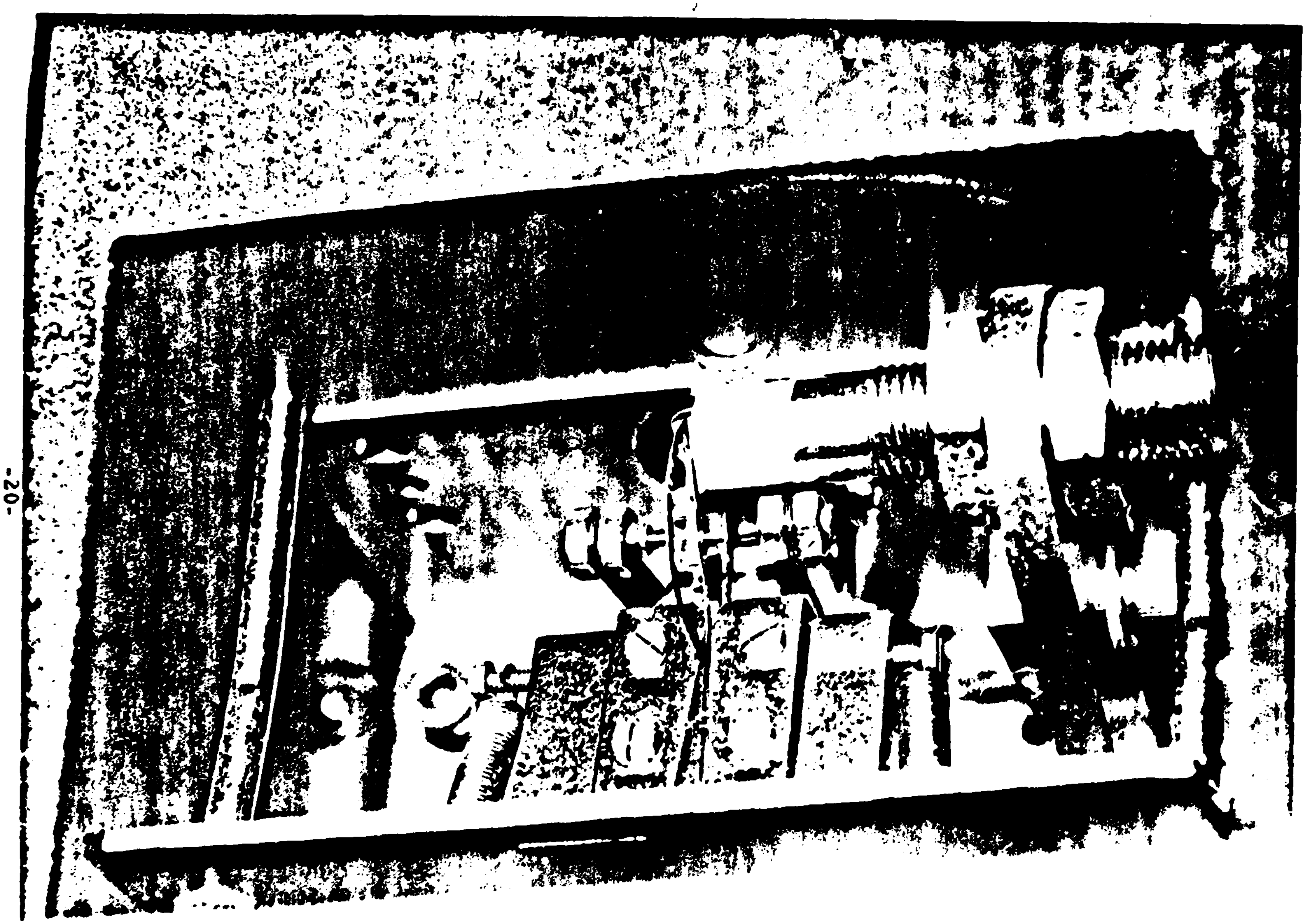


FIGURE 8 AUTOMATIC POISING WORK STATION

for workpiece velocity in rev./min. It also has LED readouts for imbalance magnitude and angle for each workstation. Signal lights indicate work in process, acceptable unit, (green) and failed unit (red). Figure 8 is a view of one work-station. The Wheel is shown resting in the loading groove, between the workpiece support bearings. In the vicinity of the spoke is the proximity transducer. When the station is initiated, a sliding cover closes one station and opens the other. The workpiece support bearings move closer together to support the pivots, while the loading groove guides separate to provide additional clearance. A sponge rubber wheel, driven by a synchronous motor, causes the workpiece to rotate at 4,000 rev./min. The laser beam is automatically pulsed to remove a tab or tabs to bring the workpiece into balance. The machine cover prevents the emission of harmful laser radiation from the work station in use, while the operator loads the other one. An interlock prevents the inadvertant opening of a fixture during the process.

In tests on wheels which were selected because they were out of tolerance, 350 units per hour were laser-balanced to specification. In operation, the machine is programmed to remove one tab. When this is done, the "heavy" spot is usually displaced to another location. In such a case, a second tab would be removed, usually sufficing to achieve balance tolerance. If the wheel is within tolerance to begin with, there is no laser action.

4.0 CONCLUSIONS

4.1 Automatic Regulation Machine

The Automatic Regulation Machine has been proven in concept by a manual prototype and in preliminary trials by a design which is, except for loading and unloading, fully automatic.

The experience gained through the limited acceptance run has led to the following observations.

4.1.1 Production Rate

Loading and unloading operations are manual, and depend upon operator dexterity. A conservative estimate would be 2 seconds for loading, allowing the operator to align and insert the workpiece, and close the fixture door; and 1 second for unloading. A skilled operator would perform faster, an unskilled one slower.

The machine requires about 1 1/4 seconds to determine the beat rate and amplitude. There is a 2-second interval programmed for this function, to accommodate slight delays which may occur at the start or at the end of this cycle.

The table advance requires approximately 1/2 second to move from the "home" position to a weld position. An increment from one weld to the next requires less time.

The ultrasonic weld time is about 1 second in duration. The ML300 welder is slightly faster than the M600, since it is more compact, the sonotrode has a much shorter motion in the ML300.

A summary of these operations is as follows.

(a)	Load	2 seconds
(b)	Read Beat Rate	2 seconds
(c)	Advance Table	1/2 second
(d)	Weld	1 second
(e)	Unload	1 second

A sequence for 1, 2 or 3 welds is shown below.

No. of Welds	1	2	3	Seconds, Ref.
	(a)	(a)	(a)	2
(Operations	(b)	(b)	(b)	2
are shown in	(c)	(c)	(c)	1/2
parentheses)	(d)	(d)	(d)	1
	(b)	(b)	(b)	2
		(c)	(c)	1/2
		(d)	(d)	1
		(b)	(b)	2
			(c)	1/2
			(d)	1
			(b)	2
	(e)	(e)	(e)	1
Total Seconds =	8.5	12	15.5	

The average time per unit can be estimated by the following expression:

$$t = \frac{3600}{8.5 + 3.5N}$$

where t = number of seconds per unit

and N = average number of welds.

The most optimistic estimate of production rate would be 2 welds per timer cycle. This implies a first weld which brings the beat rate within a few tenths of a beat below tolerance, and a final "fine tuning" weld. This would yield 232 units per hour and 1858 units per 8 hr. day. (For the purpose of this discussion, no factor for downtime, or for operator relief has been used.)

The limited experience to date has indicated 2.5 to 3 average welds per regulation cycle, yielding 208 units per hour and 1669 per day, and 189 per hour and 1515 per day, respectively.

It is felt that a significant part of the cycle is in loading. A relatively simple stack loader can be envisioned which would accept units in a magazine slide. The operator would be able to load units at any time, including during the cycle. The loading and unloading would then be accomplished mechanically, at the fixture, rather than manually. The time would not exceed 1 second for loading and unloading. A similar expression,

$$t = \frac{3600}{6.5 + 3.5N}$$

would yield the following production rate estimates. For an average of two welds, 266 units per hour, 2133 units per 8-hour day. For an average of 3 welds, 211 units per hour, 1694 units per 8-hour day.

The production rate is influenced by the computer algorithm, as discussed earlier in this report and in the instruction manual. Experience has shown that

an overly conservative algorithm results in too many welds, while a liberal algorithm produces "overshoots", whereby a beat rate is produced which is over the high limit. The most efficient balance between the two must be a trial-and-error process.

It can be concluded that the machine is capable of a production rate of 189 regulated timers per hour, as the most conservative figure, based upon an average of 3 welds per cycle; and approaching 232 regulated timers per hour at an average of two welds per cycle. With the addition of a mechanical loader, these estimates increase to 211 per hour for 3 welds and 266 for a 2 weld average.

4.1.2 Anvils

The anvil material most often used for ultrasonic welding is RDS high-speed tool steel. This is the material used in the current production anvils for producing the weld at the pivot joint. This anvil is "V"-shaped. The anvils used for automatic regulation, are flat. Flat anvil material which has given excellent results, is General Electric tungsten carbide, grade 883. The useful life is much greater than that of M-2 steel, and is feasible for the flat shape because fabrication is not difficult. Other grades have been sought and may prove superior to grade 883. Material characteristics which may enhance the useful life of an anvil are fineness of the grain, toughness and resistance to erosion. Materials such as chromium carbides, stellite and nitralloy steel are also candidate materials for this application.

Mention has been made that the regulation machine anvils are flat. It is an advantage to have flat anvils rather than shaped anvils, since lineup is important in only one plane, the plane perpendicular to the hairspring. This plane contains the leading edges of upper and lower anvils. (The upper anvil is often referred to as a "sonotrode".) These leading edges were beveled 45° in order to guide a hypodermic tube, which may have been bent, into the area between upper and

lower anvils. It was discovered, after some investigation that this angle was an indirect cause of beat rate "overshoot." The explanation follows Assume that a new timer was in the process of regulation. The first weld was .050 inches in length, and had the same shape as the anvil, i.e., a flat terminating in a 45° bevel. The second weld required a beat rate adjustment of .10 beats/second; the table therefore was displaced .0036 inches. When the second weld was made, the 45° angles on anvil and work caused a force to be exerted which displaced the timer. The second weld position, then, became the same as the first. The machine still calculated a .0036 inch additional movement. It incremented and welded over again until the two 45° angles passed each other. Then, the next weld caused a large beat rate change, over tolerance. This effect was corrected by grinding the anvil leading edges to a 90° angle. There was still a need for the bevel guide, and it was provided by a collar made of synthetic rubber, fitted over the lower anvil. A small increment of table motion now, will not result in axial forces between anvil and timer.

Provision has been made for rapid anvil replacement in both M600 and ML-300 welders. This process does not consume more than 5 or 10 minutes for either model, and two anvil replacements per shift would probably suffice. It has been found that a programmed replacement is preferred upon discovery of a worn unit or improperly regulated timers.

4.1.3 Integration into Production

It is recommended that the Automatic Regulation Machine be set up to produce timers on a continuous daily schedule. The initial daily quantity may be small when compared to the standard timer quantity. The machine operation, however, should be continuous, and the timers should be accumulated in a special lot for acceptance testing. By continuous operation, it would be possible to optimize computer algorithms, establish anvil replacement schedules, and determine best tack welding location. After a sufficiently thorough "break-in" period, the production of all M577 timers would be converted to automatically regulated timers.

4.2 Automatic Poising Machine

4.2.1 Production Rate

The automatic poising machine was tested for production rate by processing Balance Wheel Assemblies which had been preselected out-of-poise units. The machine operated at a rate in excess of 350 units per hour. In a typical unbiased production sample, it is estimated that only 15% would require tab removal. The remaining 85% would therefore not require the laser cycle, which consumes about 2 seconds. The combined rate would be over 420 units/hr. at this assumed ratio. It should be noted that this rate is greatly facilitated by the double work station since the manual loading and unloading does not take place during the machine cycle.

5.0 TEST RESULTS

A field test was conducted at the Yuma Proving Grounds in September 1977 on a lot of 120 fuzes, lot #BL-100.

These fuzes contained timers which were configured as shown on 9236711, Timer Assembly. The regulation was performed on the Manual Regulation Fixture, Tool No. 661-60001, in conjunction with a Sonobond M600 ultrasonic welder. The Balance Wheels were poised in the standard production process, not in the automatic poising machine, which was not available at that time.

The results are shown in Appendix II. The performance was equivalent to standard M577 Fuzes; if this had been a lot acceptance test, the lot would have been accepted.

A second lot of 120 fuzes, lot BL-200, was tested at the Yuma Proving Grounds in November 1978.

These fuzes contained timers which were regulated on the automatic regulation machine, and tool no. 676-80001, and balance wheels which were poised in the automatic poising machine, R01/T12.

The results are shown in Appendix I. The performance was equivalent to standard M577 fuzes. Note that the 175mm gun test is not a requirement for the M577 acceptance tests. Note also, the 75 second flight in the 155mm zone 8 gun has a high (round #29, 75.4199 sec.) and a low (round #14, 74.5012 sec.) time. With all 15 rounds calculated, the $\overline{X}$ = 74.9793 and the sigma is .1878 seconds, and the Lot Percent Defective value is within specification, which is fairly consistent with the standard production results.

5.1 Acceptance Test Performance

The acceptance test procedure of the Automatic Regulation Machine required that a specified quantity of Timers be regulated. For convenience, the computer was instructed to print out data in groups of 25 units.

A printout which is programmable as a computer output, wherein the operator has the option of:

a. execution of the printout during regulation

b. storing the data on tape

c. neither of the above

Appendix III contains 10 groups of data in 10 columns as shown.

Column 1. Complete, or Reject

Column 2. Date, month and day

Column 3. Time of day

Column 4. Unit number

Column 5. Initial frequency

Column 6. Final frequency

Column 7. Amplitude

Column 8. Number of passes

Column 9. Average regulation constant

Column 10. Run number

Note: (a) Item 4 requires a manually dialed input; used only when it is necessary to identify a particular timer. This is useful when troubleshooting timer or machine problems.

(b) Item 8; a zero means 1 weld; 01 means 2 welds, etc.

The ten groups of 25 fuzes shown in these printouts is typical of the first machine tryout.

A discussion of these results follows.

Appendix III is a synopsis of the values from Appendix II. The first column shows the reliability, or fraction of acceptable units. These vary from 92% for group 2 to 44% for group 4, with a 77% overall reliability for 250 timers. Reasons for regulation fallout are low amplitude, beat rate overshoot, non-starting and beat rate too high from the previous operation. Values found for these categories are shown in the tabulation. The number of welds is one greater than the number of passes printed out. A "pass" is defined as the incremental movement between welds. The last two columns show the number of welds and the average weld per timer.

It should be noted that the 9th column in the Appendix III computer tapes, entitled "Kcom" is an average of $\Delta X/\Delta R$, that is, the ratio of hairspring foreshortening due to the weld, to the change in beat rate. Each weld is made with a linear algorithm of the form $\Delta X = K\Delta R$ as discussed elsewhere in this report, where the value of K is determined by the hairspring properties and geometry. A value of .036 has been used in the algorithm under discussion.

Significance of the acceptance data:

Reliability. The only machine-caused timer fallout is beat rate overshoot. The reason overshoot can occur is that there is a dispersion of beat rates obtained by the incremental welding process. The K value is chosen to yield the maximum number of acceptable timers with the minimum number of welds. It has been discussed previously, that other algorithms can be used, which are superior; such as, for reference, $\Delta X = K\Delta R - C\Delta R^{e}$ for reducing beat rate dispersions, and another algorithm for initially detecting the beat rate rather than performing an initial weld. Neither of these developments was available at the acceptance test. If the beat rate overshoot fallout only is considered, and the low amplitude, non-start and high initial beat rate units not attributed to machine malfunction, the acceptance test samples would have a reliability of 192/231 or 83%.

Average Number of Welds. The acceptance test used the algorithm which welded an "initial position" before reading the beat rate. In effect, this weld was a second "tack" weld. It was felt, at the time, that an accurate point of reference was desirable. Subsequent experiments tended to favor another algorithm. In this algorithm, the beat rate is read initially, and the table is incremented from a memorized "task" location. The substitution of this new algorithm is expected to decrease the total number of welds per unit by one weld. However, the more conservative table movement, may increase the average by a fraction. The discussion in section 4.1.1 regarding an optimum number of welds, a small fraction greater than 2 welds per unit, would seem to be an attainable goal during subsequent programs or testing.

Initial Frequency. It is necessary to select a location for the "tack" weld which would always result in slow beat rate, no matter what the part's dimensional variations are, within tolerance. This can be done by trial and error for a particular lot. However, a knowledge of the relationship of the principal variables will facilitate control of the regulation process. If it is assumed that the Ni-Span-C hairspring wire is manufactured to a nominal diameter of .00850 inches, the balance wheel inertia is 58.833×10^{-9} lb/in sec.^{2}, then the beat rate will be a function of the effective length of the hairspring and its diameter.

$R = 1.31278 \times 10^6 \, d^2 L^{-\frac{1}{2}}$ where d is the diameter, L is the length and R is the rate. If a lot of hairspring wire with a different diameter is used, the effective welding point will change; .0001 inch in diameter change will cause a 1/16 inch change in weld location. These parameters should be monitored to avoid permitting the weld location to approach too close to the outer end, or to the support.

If it becomes necessary to alter the "tack" welding point, the new dimension should be entered into the algorithm.

APPENDIX I

AUTOMATIC BEAT RATE REGULATION MACHINE

FOR THE

M577 FUZE TIMER

INSTRUCTION MANUAL

BULOVA SYSTEMS & INSTRUMENTS CORPORATION

AUTOMATIC BEAT RATE REGULATION MACHINE

FOR THE

M577 FUZE TIMER

INSTRUCTION MANUAL

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Murray Braverman
Murray Braverman
Senior Project Engineer

D.I. 2,094

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List of Illustrations

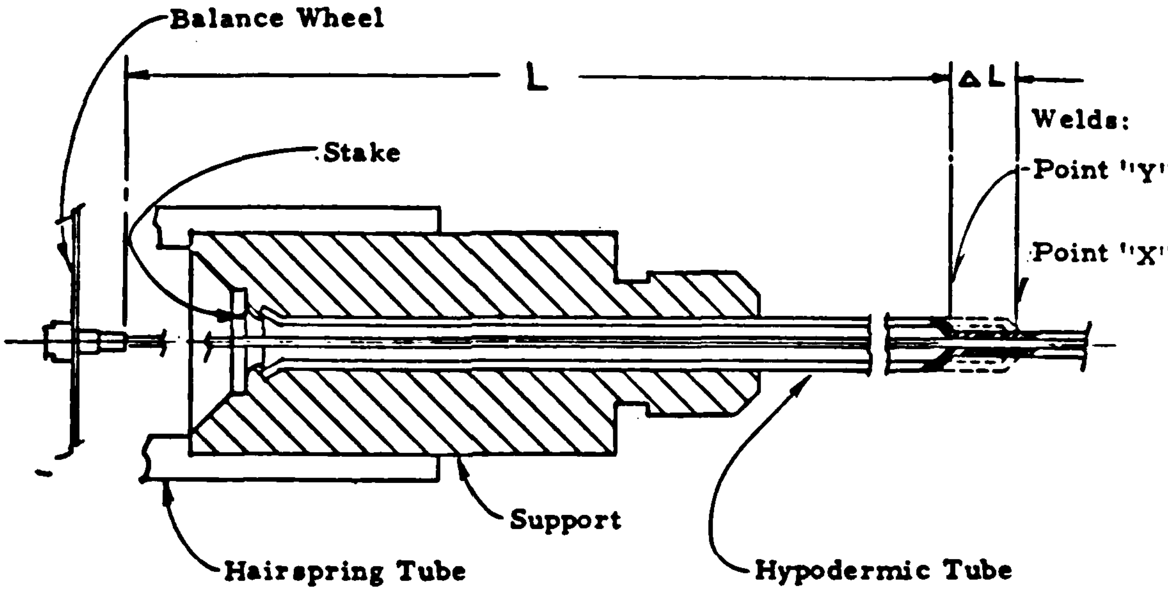
1.0 INTRODUCTION

1.1 The Automatic Regulation Machine is an electromechanical system designed to adjust the beat rate of the M577 Mechanical Time Fuze Timer to specified limits.

1.2 The basic principle which makes this process possible is contained in Timer Modification ECP NOR A 882030 and as modified by ECP's A9A3062 through A9A3070, covering an ARRADCOM in-house ECP for Automatic Regulation as defined by 9236711. This enables the machine to shorten the active length of the Hairspring. Figure 1 shows the essential features. As the Timer runs while the Hairspring is attached at point "X", a ΔL is calculated. When rewelded at "Y", a faster beat rate results.

1.3 The Machine nests the work piece Timer in a fixture. The fixture automatically starts the Timer, and is equipped with sensors which pick up beat rate and amplitude data. A computer, with appropriate programming, processes these data, and calculates the necessary length change. A servo table, upon which the fixture is mounted, is caused to move to the new location, and a new weld is made. Indicator lights inform the operator of acceptance or rejection of the unit in process. Data are also displayed on printouts and may be recorded for later study or sampling. All necessary power supplies, meters and housings are mounted in two consoles, shown in Figure 2.

1.4 The program contains algorithms for various functions. The algorithm for regulation will be described. With reference to Figure 1, point "X" is the location of the "tack" weld, made upon the subassembly. This weld locates the Balance Assembly at the proper "deadbeat" and "endshake" dimension. After the Timer is assembled and loaded into the machine, the table is moved to a predetermined location, just slightly beyond the "tack" weld, where weld "Y" is made. Based upon the new beat rate obtained, the algorithm calculates a new length increment, and makes another weld. This process is repeated until the rate is within tolerance. Alternatively, instead of a predetermined first



PRINCIPLE OF AUTOMATIC REGULATION

FIGURE 1

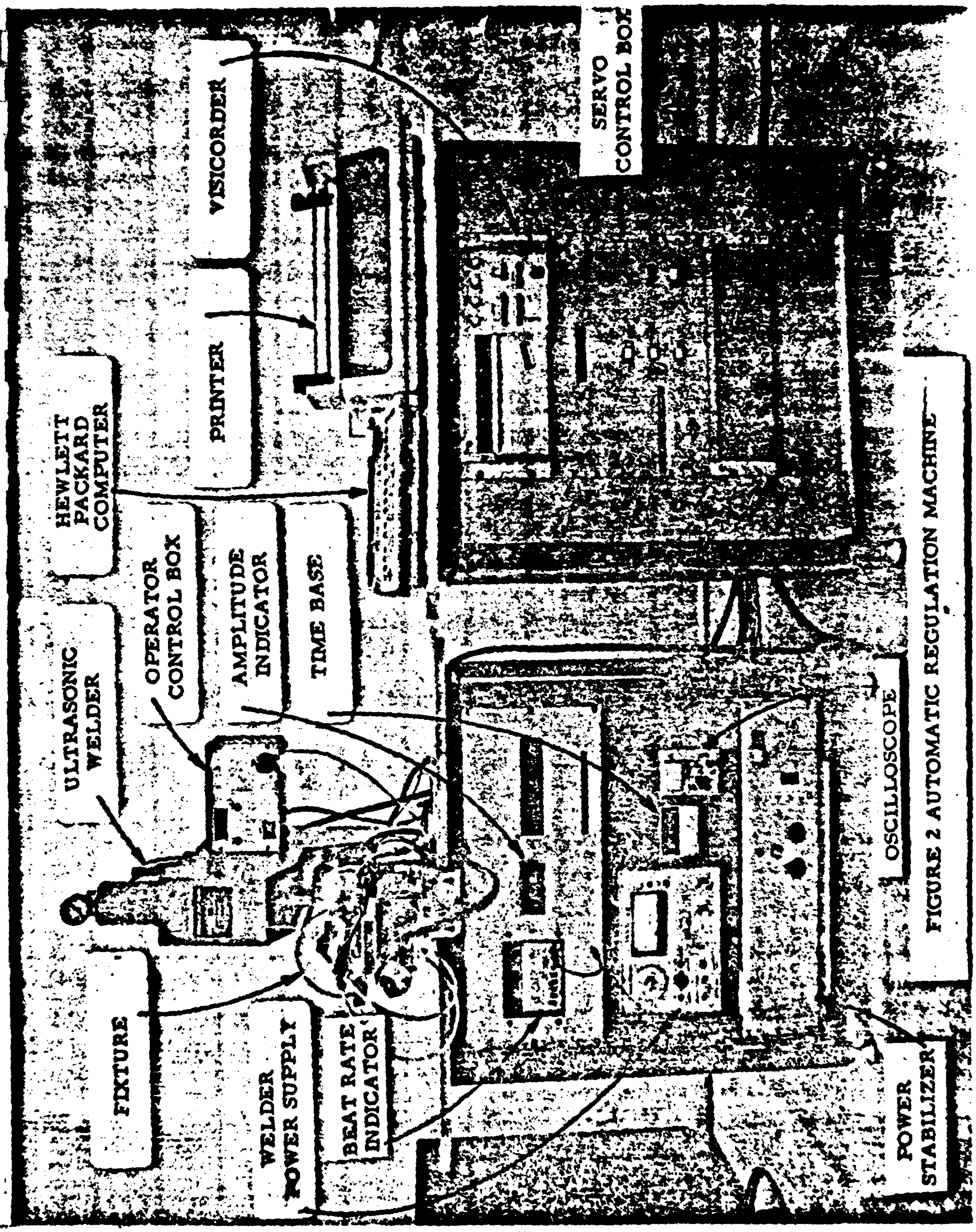


FIGURE 2 AUTOMATIC REGULATION MACHINE

weld location, another algorithm may be used. The beat rate may be measured first; this rate is associated with the "tack" weld. The location of this weld, although made previously in another machine, is part of the algorithm. The weld at "Y" is now the calculated one. This algorithm has the advantage of one less weld, but the disadvantage is that the "tack" weld must be held to a closer location.

The calculating algorithm may also take different forms. The simplest one is of the form $\Delta s = K \Delta R$ where Δs is the table movement, ΔR is the required change in beat rate, and K is a constant which depends upon the hairspring wire diameter. In order to make the algorithm more conservative, one having the form $\Delta s = K\Delta R - C\,\Delta R^{E}$ could be used. C and E are suitable constants. The second term of the equation reduces the table movement to compensate for greater dispersions when large table increments are encountered. The algorithm may be readily changed to implement improvements which may be made during production, or to accommodate different wire diameters.

1.5 In addition to the indicator lights, there is a 2-inch tape which records detailed data on each welding cycle, giving date, time, serial number, table position, beat rate etc. A sample tape is shown in Figure 3. A large printout is also made, which summarizes the cycle data and which also indicates acceptance or rejection. A sample is shown in Figure 4.

1.6 Description of Equipment

The Automatic Welding Regulation Equipment consists of two enclosed operating platforms mounted on mainframes enclosing support electronic equipment. These components are the welding mainframe and the computer mainframe.

The welding mainframe contains the following pieces of equipment:

1. Bulova Mark VI Beat Rate and Amplitude Chassis.
2. Bulova Photocell Amplifier, Shock Resistant.

3. Bulova optical reflective light source pick up.
4. Bulova logic interface panel.
5. Bulova power distribution panels.
6. Anorad Model 233 Serial 1 single axis position platform.
7. Sonobond welder and support electronics, Model M600 with LED RF output meter.
8. Model Hewlett Packard 5300B measurement system including H. P. 5370A high resolution counter and 5312A HPIB interface.
9. Model 1230 Weston digital voltmeter.
10. Model 5909A Hewlett Packard digital clock.
11. Model SC 501 Tektronix oscilloscope.
12. Bulova positive pressure ventilation system.
13. Bulova fuze air cylinder holding fixtures with clamp interlock switches.
14. Bulova protective safety shield with cycle start switch.

1.6.1 The Computer mainframe consists of the following:

1. Model 9825 Hewlett Packard computer calculator.
2. Model9871A Hewlett Packard printer with 98032A interface.
3. Model 1508B Honeywell visicorder.
4. Bulova computer mainframe power distribution panel.
5. Model 233 Serial 1 electronic logic driver.
6. Model 9878A Hewlett Packard I/0 expander.
7. Bulova positive pressure ventilation system.
8. 2 each Hewlett Packard Model 98032A 16 bit interface.
9. 2 each Hewlett Packard Model 98033A BCD interface.
10. 1 each Hewlett Packard Model 98034A HPIB interface.

BULOVA SYSTEMS & INSTRUMENTS CORPORATION

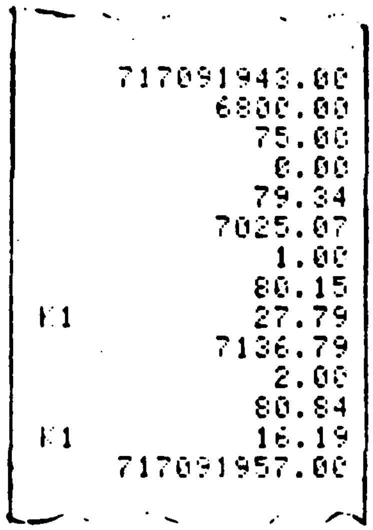

```
      717091943.00
           6800.00
             75.00
              0.00
             79.34
           7025.07
              1.00
             80.15
K1           27.79
           7136.79
              2.00
             80.84
K1           16.19
      717091957.00
```

Figure 3 Hewlett, Packard 9825 Thermal Printer Data

The sample of 2-inch wide tape printout illustrates data output.

Data from the computer are presented in three places; the L.E.D. panel on the computer terminal, the 9871A Printer, which is a wide-sheet hard copy printer and a 2-inch wide thermal printer on the terminal body.

The inset shows a printout as it is made by the computer. The explanation of each line of data is follows.

1. **Date-time code** 717091943.00
   - **Month of July** 7
   - **Date** 17
   - **Hour of Day, (0-24)** 09
   - **Minutes, (0-60)** 19
   - **Seconds, ((0-60)** 43
2. **Initial Table location** 6800.00
   (actual location is .6800 inch from "home" position)

3.	Workpiece serial number		75.00
4.	Cycle counter		0.00
5.	Beat Rate .... (resulting from weld at location of 2.)		79.34
6.	New Table location		7025.07
7.	Cycle Counter		1.00
8.	Beat Rate .... (resulting from weld at location of 6.)		80.15
9.	Rate of change of Hairspring length with respect to rate, between last two welds	K1	27.79
10.	New Table location		7136.79
11.	Cycle counter		2.00
12.	Beat Rate (resulting from weld at location of 10.)		80.84
13.	Rate of change of Hairspring length with respect to rate, between last two welds	K1	16.19
*14.	Date-Time Code		717091957.00

*Note: 14 seconds have elapsed from start to finish

	Date	Time	Unit#	Initial P	Final P	Amplitude	[illegible]	[illegible]	[illegible]
COMPLETE	06/26	09:39:12	0001	79.739	80.010	114	0.	0.01357	0001
COMPLETE	06/26	09:39:12	0001	79.739	80.010	114	01	0.01357	0001
COMPLETE	06/26	09:39:27	0001	79.530	79.929	119	01	0.01950	0002
COMPLETE	06/26	09:39:43	0001	79.910	79.960	192	02	0.01191	0001
COMPLETE	06/26	09:40:03	0001	79.570	79.990	101	02	0.01299	0004
COMPLETE	06/26	09:40:25	0001	80.060	80.940	110	01	0.01025	0005
COMPLETE	06/26	09:40:40	0001	79.790	80.930	107	02	0.03171	0006
COMPLETE	06/26	09:40:50	0001	79.799	80.790	125	02	0.09999	0007
COMPLETE	06/26	09:41:27	0001	79.070	80.390	102	02	0.01991	0009
COMPLETE	06/26	09:42:05	0001	79.440	79.930	111	03	0.01542	0011
REJECT	06/26	09:42:30	0001	79.310	80.910	050	03	0.00000	0012
REJECT	06/26	09:42:44	0001	79.059	79.900	014	02	0.00000	0013
COMPLETE	06/26	09:42:57	0001	78.059	79.930	199	02	0.03636	0014
COMPLETE	06/25	09:43:17	0001	79.359	80.770	107	04	0.05471	0015
REJECT	06/26	09:43:05	0001	80.000	79.929	019	03	0.00000	0016
COMPLETE	06/26	09:44:06	0001	79.139	79.950	195	02	0.03150	0017
COMPLETE	06/25	09:44:59	0001	79.919	80.770	120	02	0.06009	0019
COMPLETE	06/26	09:45:17	0001	78.340	80.020	1??	02	0.01179	0020
COMPLETE	06/26	09:45:30	0001	79.519	79.960	104	02	0.02554	0021
COMPLETE	06/26	09:46:21	0001	78.739	80.790	127	01	0.01971	0023
COMPLETE	06/26	09:46:59	0001	80.129	80.790	121	01	0.01273	0025
COMPLETE	06/26	09:47:15	0001	79.410	79.940	119	02	0.03996	0026
COMPLETE	06/26	09:50:29	0001	80.099	80.830	126	02	0.01799	0028
COMPLETE	06/26	09:50:47	0001	78.731	80.770	122	02	0.04497	0029
COMPLETE	06/26	09:51:08	0001	79.910	80.930	999	02	0.03229	0030
COMPLETE	06/26	09:51:26	0001	80.230	80.540	123	02	0.01672	0031
COMPLETE	06/26	09:51:45	0001	79.570	79.790	120	02	0.01516	0032
COMPLETE	06/26	09:52:04	0001	80.117	80.910	121	03	0.04959	0033
COMPLETE	06/26	09:52:24	0001	78.130	79.920	125	02	0.03570	0034
COMPLETE	06/26	09:52:46	0001	79.553	79.990	121	02	0.01252	0035
COMPLETE	06/26	09:53:35	0001	79.597	80.930	129	03	0.03773	0036
COMPLETE	06/26	09:53:32	0001	79.210	80.920	121	02	0.01501	0037
COMPLETE	06/26	09:53:50	0001	78.490	80.370	116	03	0.04512	0039
COMPLETE	06/26	09:54:13	0001	79.969	80.960	120	0?	0.03190	0039
COMPLETE	06/26	09:54:32	0001	79.799	80.770	121	02	0.01776	0040
COMPLETE	06/26	09:54:49	0001	79.650	78.829	111	02	0.04171	0041
COMPLETE	06/26	09:55:07	0001	79.157	80.330	123	02	0.03473	0042
COMPLETE	06/25	09:55:22	0001	79.940	79.340	124	01	0.06027	0043
COMPLETE	06/25	09:55:46	0001	79.999	80.950	121	01	0.06191	0044
COMPLETE	06/26	09:56:09	0001	79.370	80.750	119	02	0.03779	0045
COMPLETE	06/25	09:56:32	0001	78.319	80.960	119	01	0.01116	0046
COMPLETE	06/26	10:56:59	0001	79.179	79.300	126	07	0.32757	0047
COMPLETE	06/26	09:57:11	0001	79.999	80.249	175	12	0.91591	[illegible]
COMPLETE	06/25	09:57:30	0011	79.199	[illegible]	126	[illegible]	[illegible]	[illegible]
COMPLETE	06/25	09:57:51	0011	70.517	[illegible]	170	12	0.91691	[illegible]
COMPLETE	06/25	09:54:11	0001	80.199	49.020	11?	[illegible]	0.01915	[illegible]
COMPLETE	05/25	10:57:01	[illegible]	79.559	79.900	122	[illegible]	0.01295	[illegible]
COMPLETE	06/25	10:51:31	0711	79.921	99.129	[illegible]	[illegible]	0.01607	[illegible]
COMPLETE	0./25	99:50:22	0191	49.013	09.909	111	11	1.02577	[illegible]
COMPLETE	0./25	21:59:15	[illegible]	19.107	70.111	[illegible]	12	0.01190	[illegible]

FIGURE 4 PRINTOUT OF WIDE TAPE

2.0 AUTOMATIC REGULATION MACHINE

2.1 Principle

The process of beat rate adjustment depends upon changing the natural frequency of the spring-balance system of the Timer. This is accomplished by changing the active length of the Hairspring, i.e., the spring constant.

In the system being described, the Hairspring is initially welded to the Hypodermic Tube at point "X" on Figure 1, at which location the beat rate is chosen to be slow. This location is selected by trial, so that all units will resonate at a frequency low enough to be consistent with the regulation process.

When the Timer is assembled and in the process of regulation, the computer algorithm activates the system to perform a weld at point "Y", foreshortening the active length of the Hairspring by a length of " ΔL " as shown on Figure 1. The process takes place while the timer is running.

2.2 Background

The reason for the selection of Hairspring length as the most practical parameter to control for beat rate regulation, is as follows. The assumption, with negligible error, is that the Balance Hairspring system is a free-running, undamped, torsional pendulum, vibrating in simple harmonic motion. The natural frequency may be expressed as:

$$f = \frac{1}{2\pi} \sqrt{\frac{K}{I}}$$

where K = Hairspring restoring torque constant

I = Balance Wheel moment of inertia

f = natural frequency

The Hairspring restoring torque can be expressed as a function of wire diameter and length:

$$K = \frac{\pi d^4 G}{32 \ell}$$

where d = wire diameter

ℓ = active Hairspring length

G = modulus of rigidity = 9×16^6 lb/in^2

Combining these equations,

$$f = 149.6\, d^2 \ell^{-\frac{1}{2}} I^{-\frac{1}{2}}$$

The total differential of the frequency as a function of wire diameter, length and Balance Wheel moment of inertia is,

$$df = \frac{\partial f}{\partial d} dd = \frac{\partial f}{\partial \ell} d\ell + \frac{\partial f}{\partial I} dI$$

The effect on frequency of finite variations of d, ℓ and I are,

$$\Delta f = 9,331\ \Delta d - 13.5\,\Delta \ell - 393 \times 10^6\,\Delta I$$

The following variation of each parameter will cause a change of .10 beat/sec.:

Δd = 5.4×10^{-6} inches

$\Delta \ell$ = .0037 inches

ΔI = 1.27×10^{-10} lb. in. sec.^{2}, or, in terms of thickness, 9×10^{-6} inches.

It is evident that the Hairspring active length is the only parameter presenting the possibility of control.

These calculated values are in good agreement with observed values.

It should be carefully noted that, for a constant beat rate and Balance Wheel inertia, a .0001 inch change in the wire diameter changes the active Hairspring

length about 1/16 inch. A change of .0001 inch in the Balance Wheel thickness, with a constant wire diameter and length changes the beat rate more than .5 beats/sec. Therefore, it is necessary, for the achievement of a smooth flow of Timers through the regulation process, to exercise tight control over these dimensions.

To illustrate the foregoing with calculated values, let the beat rate be 80.74 beats/sec., the Balance Wheel moment of inertia = 54.833×10^{-9} lb. in. sec.^{2}. Then the Hairspring length as a function of its diameter, to keep the rate constant, is expressed as $\ell = 264.3665 \times 10^6 d^4$, where ℓ is the active spring length and d is the diameter. Some representative values follow:

WIRE DIA., inches	WIRE LENGTH, inches	LENGTH CHANGE, inches	
.0081	1.138	.055	
.0082	1.195	.057	
.0083	1.255	.059	
.0084	1.316	.062	Present
.0085	1.380	.064	Bulova
.0086	1.446	.066	Range
.0087	1.515	.068	
.0088	1.585	.071	
.0089	1.659	.073	
.0090	1.735	.076	

The exact frequency deviation may be determined from the visicorder by knowing the following:

1. the paper speed in inches per second
2. the determination of the error in cylces per inch

The error is then:

$$Fe = \frac{\text{cycles}}{\text{inch}} \times \frac{\text{inches}}{\text{sec}}$$

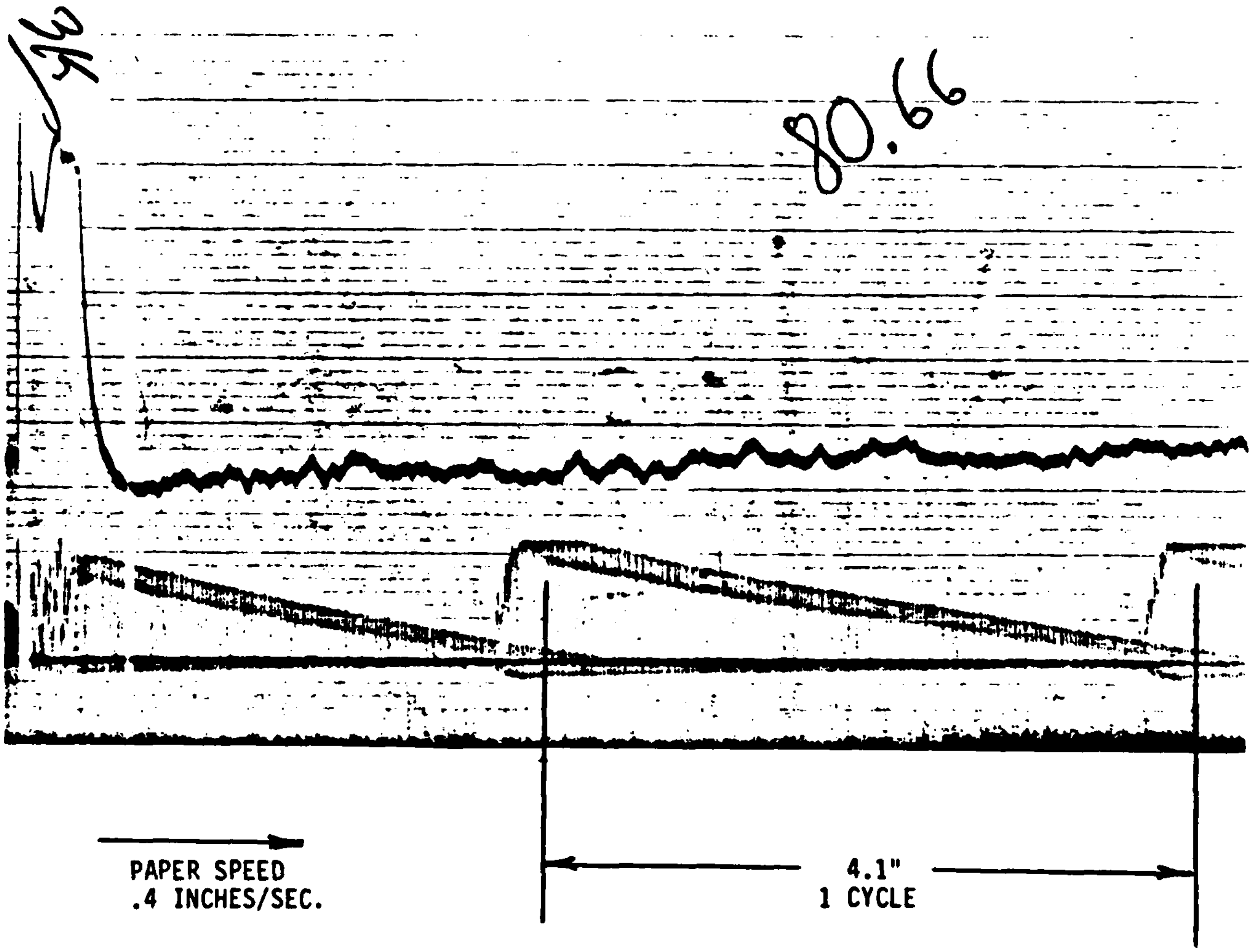


FIGURE 5. SAMPLE VISICORDER TRACE

It is not necessary to record a full cycle of error. We determine the angle of the tips of the pulses and use the full scale deflection of the visicorder. The full cycle of error may be determined from the following expression:

$$\text{Cycles/inch} = \frac{\text{Full scale deflection in inches}}{\text{Tangent of the angle of pulses}}$$

Therefore

$$\text{Frequency error} = \frac{\text{Full Scale (inches)}}{\text{tangent of angle}} \times \frac{\text{inches}}{\text{sec}}$$

2.3 Hairspring Tack Welder

Figure 6 shows the "tack" welder. This is the initial fastening between the Balance and Hairspring Assembly and the Plate No. 1 Assembly, and it determines the endshake, deadbeat position and initial beat rate.

In operation, the Fixture locates Plate No. 1 axially against a bushing. The angular position is determined by a locating pin, and provides welding orientation at the same attitude as the Regulation Machine.

The Balance Wheel is located by the engagement of its detent notch against a locating pin. A shim determines the endshake and a spring-loaded finger provides clamping.

Note that the ML-300 Sonobond Welder is shown in the photograph. Optionally an ML-600 model may also be used to perform the operation.

2.4 Fixture, Servo & Sensors

2.4.1 Figure 2 shows the Regulation. The method used for nesting the Timer into the fixture may be understood by referring to Figure 7,

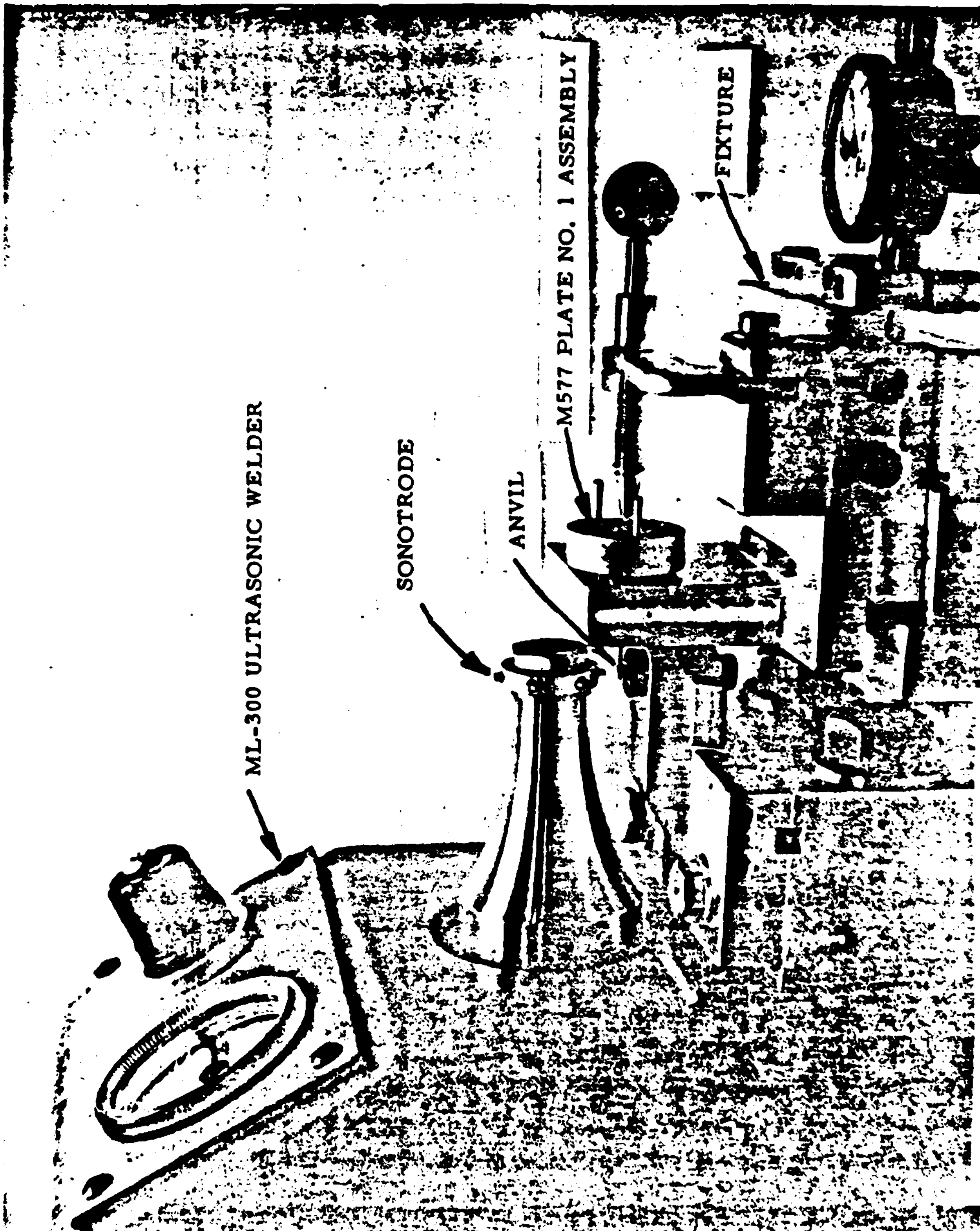


FIGURE 6 TACK WELDING STATION

"Interface Between M577 Timer and Automatic Regulation Machine". The Plate No. 1 flat nests on the Fixture jaws, as shown in the cross section, which provides a unique angular orientation. The bottom of the jaw acts as a stop to locate the center line. When actuated by the Air Cylinder, the Scroll Guide moves against the Timer Assembly. At contact, the Scroll is centered by the Scroll Guide, enabling the Spring Loaded bearing to engage. Upon further motion, the Timer's Hairspring Tube enters the Guide Bushing, until the Optical Pickup enters the appropriate opening in Plate No. 1. The Spin Detent Retractor then deflects the Spin Detent, releasing the Balance Wheel, starting the Timer.

The Cover has been designed to prevent injury to fingers and also, to protect the fixture. There is a solenoid spring lock which permits the Cover to be opened only when energized. There is a sensor which enables the computer to determine whether the Cover is closed. The regulation cycle may be initiated by a panel switch. Alternatively, the Sensor may be used to initiate the cycle.

The Fixture has been designed for a minimum of maintenance, and no adjustments.

2.4.2 The Servomechanism which accomplishes the Fixture movement is a system comprising a machine slide with a one-inch movement, a lead screw to move the slide, a servo motor to power the screw, a master scale and scanner system for position control and an electronic control panel which interfaces between the servo and the computer. The servo system is capable of a resolution of .0001 inch, which is adequate for the purpose. A feature of the servo motor is that it has a "home" position from which the settings are measured. Each time the fixture cycles, this position is used to ensure repeatability of table settings.

2.4.3 Two types of proximity sensors are used on the fixture.

A magnetically operated Hall effect switch is used to monitor the open or clamped condition of the fixture, and a similar one is used to monitor the open or closed condition of the Cover. These devices operate without contact and have been performance-tested by the manufacturer to more than 12 billion operations. The dimensional operating range is in excess of 1/16 inch. The output is in digital form enabling convenient interface with the computer.

A proximity sensor based upon the Eddy current principle is used in the fixture to detect the presence or absence of a workpiece. This device also operates at a distance and range in the order of 1/16 inch, and is designed to detect the presence of metals.

2.5 Ultrasonic Welder and Sonotrodes

The method used for fastening hairspring wire to hypodermic tubing in the automatic regulation process was similar to the pre-existing method, with some changes. The changes were necessitated by different requirements and by options in the welder type.

The tacking and regulation welders perform welding which is not required to pass through a bushing, as was required of both welds in the previous system. The tubing diameter is greater than the previous design. Therefore, the anvil shape may be modified to a more efficient shape. A V-shaped anvil and sonotrode, with a greater angle, was chosen for this application, and yielded good results. The V tends to centralize the wire inside the tube. The opening of the V is wider than the previous design, permitting a greater lateral dimensional tolerance in the insertion of the workpiece.

Either the M600 or the ML-300 Sonobond Welder may be used on tacking or regulation operations. The ML-300 permits a multiple-toolhead sonotrode design to be used, which facilitates set-up because of the ease with which a fresh sonotrode may be set. Both units use identical power supplies.

The V anvils are made of M-2 steel. The regulation machine anvils are flat and are made of tungsten carbide. The carbide anvils are inserts, press-fitted into aluminum holders. The M-600 welder uses individual anvils which are threaded in such a manner as to effect proper angular orientation when the anvil is torqued into position.

The operational procedures and other matters relating to the set up operation, maintenance and troubleshooting of the welders are adequately covered by their respective handbooks. In addition, other factors were discovered in the pursuit of the subject programs. For the welding of the hypodermic tube to

hairspring wire, best reults are obtained with a high ram speed, giving maximum impact upon the workpiece. It was found that sticking between carbide anvil and workpiece sometimes occurred when new anvils were installed. A smear of lubricating oil on the anvils eliminated the problem. As an alternative, it is possible to program the servo table to retract before advancing, without incurring additional processing time. This will break the sticking anvils loose before repositioning. The best finish on the working surfaces of the carbide anvils is a ground finish of approximately 32 microinches RMS with the grinding direction perpendicular to the workpiece axis.

2.6 Computer and Software

The Hewlett Packard 9825 Computer was selected from among many candidate computers for several reasons.

(a) It is sensor-oriented. The Hewlett Packard Company makes many scientific instruments, all of which are easily interfaced with the 9825 in a manner similar to the present requirements.

(b) It is readily programmable by anyone familiar with BASIC language.

(c) It is capable of being operated in a time sharing mode. At the time these decisions were made, this seemed important. At the present time, it is considered more cost-effective to have separate computers for each welding station, since the cost of a single day's downtime exceeds the cost of one computer.

(d) The size of the memory and the ease with which either continuous data, or randomly selected data concerning production may be obtained, is similar to a large computer. The memory size may be very readily increased with the addition of tape or disc modules. Thus, production control, quality control and troubleshooting procedures are greatly facilitated.

(e) The Hewlett Packard Company is large and reputable and is likely to be solvent for the forseeable future.

(f) The Bulova Systems & Instruments Corporation has had much favorable experience with the Hewlett Packard Company and confidence in their products, therefore, is high.

2.7 Theory of Operation of the Mark VI Beat Rate Amplitude Instrumentation

The Mark VI Beat Rate Amplitude instrumentation has the specific function of converting an optical signal derived from the balance wheel of the M577 fuze to information yielding the absolute beat-rate and balance wheel amplitude in digital form. This information is used to provide the basic data for automatic frequency correction and acceptance of the fuze under the regulation process.

The balance wheel has 60 black spaces and 60 white spaces located around the rim of the wheel mass. One black and white space pair represents 6 degrees of arc of the balance wheel rim. An illumination source and a phototransistor enables one black or white stripe to be optically resolved at any particular time. The output of the transistor through a fiber optic transmission system varies the impedance of a load source in such a manner as to produce an electrical signal suitable for further processing. A remote low-noise preamplifier serves to improve the signal-to-noise ratio, and as a high-pass filter for the input signal. The output of the preamplifier is fed to an additional amplifier that also has a high-pass filter and serves to amplify the signal further for oscillographic presentation, amplitude presentation and further processing.

The signal is then passed through a 1000 cycle high-pass LC filter to reject all components of frequency usually common to vibration associated with fuze firing and test environments. This processed signal is now fed to a multi-stage limiter to allow the information to be independent of the magnitude (voltage amplitude) and solely dependent on the frequency-modulated portion of the signal. A special LR frequency-sensitive detector is used to extract the beat rate information from the sinusoidal frequency-modulated stripe signal. The modulating signal recovered is the 80-cycle beat rate component from the basic 1000 to 7000-cycle carrier signal.

A broad-band 80-cycle filter is used to enhance the signal to improve the noise ratio of the derived modulation product. This signal is then amplified and limited in several successive stages. The signal is then shaped to a rectanglar wave for the frequency meter input and the visicorder beat rate error presentation circuit.

The beat rate output signal is initially divided by two by an internal toggle flip-flop and then divided by an additional 30 times divider. The resultant low frequency (80.74 divided by 60 = 1.346) is about 1.35 cycles per second. The signal now is fed to an automatic recipromatic counter (Hewlett Packard 5300B/5307A/5312A). The counter measures two periods of the low frequency output signal and presents the resultant readout in a frequency format. The counter is used in the RPM position to override a 5-cycle digital filter cutout when the counter is used in the frequency position. Since a reading is taken over two .743 second intervals (1/1.35), the total measurement time for a final reading is 1.49 seconds which embraces the integration of 120 cycles of actual clock frequency. It has been determined that a measurement of clock frequency must include in the order of 100 cycles to produce an acceptable average value. The frequency measured by the HP 5300B/5307A/5312A is initiated by control lines from the HP 9825A computer system in accordance with program requirements through the 5312A ASC II interface.

The analog signal from the optics is taken from the amplifier in the Mark VI and is fed to an integrator board. The board is labeled "Tachometer Board" and serves as a converter that presents a direct current output proportional to the number of stripes per beat. Stripes per beat is a direct indication of the amplitude of the balance wheel. A digital voltmeter with a BSC digital output is used to present a visual indication of amplitude and to serve the input requirement of the computer program. Also,a separate direct current output drives a galvanometer for the amplitude presentation on the 1508B visicorder.

A special frequency comparator is used to provide means for measuring the beat rate of a fuze from the viscorder trace output. This output provides a means for determining the beat rate trend through-out the entire interval the clock is in operation. If the frequency is exactly nominal, a series of equal-height pulses will be generated. If an error occurs, the series of pulses will vary in height at a rate proportional to the deviation from the nominal beat rate. The direction of the slope of the peaks of the pulses is an indication of whether the beat rate is lower or higher than the nominal beat rate. This method of measurement will show beat rate trends under several conditions of noise, providing the ramp function is visible in any degree through the noise signal.

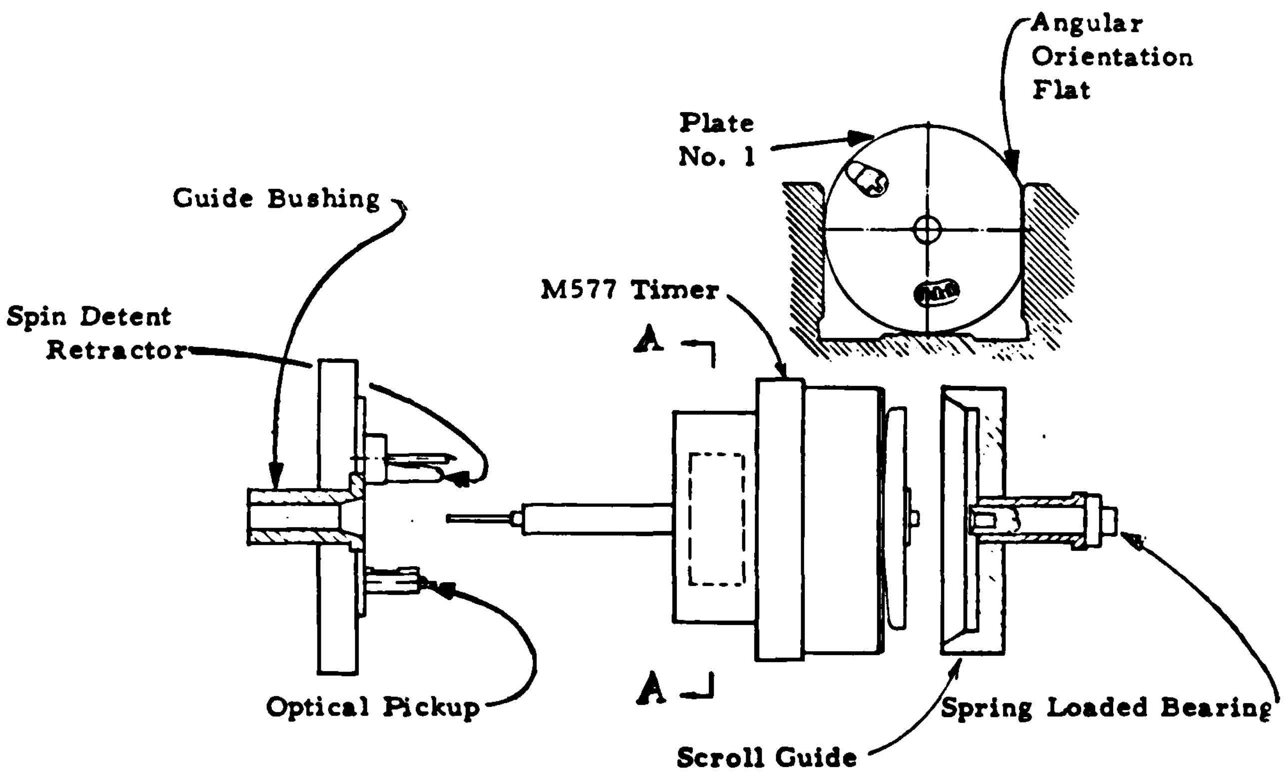
The comparator used to provide the frequency output consists of a saw-tooth wave generator of good linearity. The repetition rate of the saw-tooth wave is controlled by a standard crystal-controlled synthesized source. The saw-tooth source is fed to a proportional "and" gate together with a fuze frequency finite width pulse generator. If the frequency of the standard saw-tooth is exactly the same as the beat rate pulse, the resultant output pulses will always be of the same height. This is because the pulse will occur at the same height, coincident with the standard saw-tooth. If the frequencies differ, points of coincidence will occur at succesive,changing magnitudes of the standard saw-tooth resulting in a pulse train whose peaks will represent a ramp function indicative of the difference of the frequencies of the two signal sources. Mathematical differentation of this smoothed pulse signal will yield a direct current whose voltage is directly proportional to frequency deviation. This method is used on the Bulova Mark III devices for direct-reading of frequency with a meter or analog-to-digital converter. The advantage of this method of measurement is that at the nominal frequency, the error becomes non-existent.

3.0 MACHINE - TIMER INTERFACE

In order to accomplish the goal of automatic regulation in an efficient manner, it is necessary that the prescribed sequence of machine operations takes place in an orderly manner.

This, in turn, requires that there be appropriate mechanical interaction between the M577 Timer and the Machine, consistent with methods for location, clamping, beat rate and amplitude detection, and regulation.

Figure 6 is a graphical representation of the machine - timer interface. The flat on Plate No. 1 provides angular orientation; the operator loads the Timer into the fixture jaws with the proper alignment. The lower part of the jaw provides a stop to hold the Timer centerline height. The operator now starts the cycle. The Scroll guide moves toward the Timer, tending to center the Scroll, and bring its shaft journal into alignment with the spring-loaded bearing. As the Timer progresses in its movement, its tube enters the guide bushing, whose face acts as the stop against which the Timer is finally clamped. The optical pickup and the spin detent retractor enter their respective openings in Plate No. 1. The retractor swings radially to lift the detent and release the Balance Wheel, starting the Timer.



INTERFACE BETWEEN M577 TIMER AND AUTOMATIC REGULATION MACHINE

FIGURE 7

4.0 SOFTWARE DESCRIPTION

At the present time the Hewlett Packard model 9825A Computer Calculator has been programmed to output to its own printer and an auxiliary Model 9871A printer. The software is arranged to allow full data documentation and storage for 2,000 fuzes per cassette. Simple programming changes can be made to allow minimum documentation and storage. The fastest production capability can be obtained by rendering the printers inoperative and allowing the COMPLETE, and REJECT lamps to serve as the only criteria for the regulation operation.

When power is first applied, the 9825A computer has the ability to load the working program automatically. A yellow lamp will light near the programming cassette to indicate loading is taking place. When the loading is finished a "0-RUN 1" - DATA message will appear on the computers LED display. While only 0 and 1 are displayed as enter options the following modes of operation are available if keyed in to satisfy the initial enter statement. After the number is keyed in the "CONTINUE" button is pushed.

0. This is the run mode allowing automatic regulation of fuzes from number one to 200,with automatic storage after a file number is selected and the two-hundredth unit is regulated.

1. This entry asks for a file number then loads the desired file for subsequent printout. This mode allows a starting number and finishing number for any continuous group readout or individual fuze readout. The data recorded and retrived consist of a "COMPLETE" or "REJECT" status, date and time of regulation, fuze identification number, initial frequency after a first-reference weld, final frequency after regulation, balance wheel amplitude, balance wheel constant, and run number.

2. This entry presets a starting and finishing run number. The storage routine occurs at the finishing run number.

3. This entry allows a "sort" routing. This routine allows for the printout of only "COMPLETE" fuzes or, if desired, only "REJECT" fuzes. In the other data parameters a "HI" limit entry and Low limit entry is established to sort a specific fuze within particular parameters. Sorting is accomplished, using all parameters (COMPLETE, REJECT, TIME, FUZE NUMBER, INITIAL FREQUENCY FINAL FREQUENCY, AMPLITUDE, SPRING CONSTANT AND RUN NUMBER) Mean, standard deviation and number of units are computed for initial frequency, final frequency amplitude and spring constant.

711: This entered number allows an updated program to be stored on the tape in case the main program is changed.

712: This number loads the special function keys on the computer. These keys allow manual operation of some of the actuators of the machine cycle and manual program functions.

Special Functions

1. Reset
2. Clamp Unit
3. Unclamp Unit
4. Weld
5. Home (Anorad Table)
6. Lamp Test
7. Anorad Test Routine
8. Store data
9. Visicorder On
10. Visicorder Off
11. Run 2 (without losing data)
12. M(22) displays current spring constant

Shift 1. Open Hood Lock

713: Stores data on a marked tape.

714: Marks a clean tape and deposits one file (200 Units) in a selected file; erases all other files.

577: This number generates a list of the program and writes the date and time when the list has been generated.

233 "ANORAD". This entry enables a table-positioning routine. The table may be positioned to 0 to .9999 (or up to the high limit position) inches. A number greater than 1 loops the program back to "RUN DATA" select position.

999: "MON". This entry may be used when the fuze identifier is 0000. A fuze beat-rate amplitude, and time will be displayed on the LED calculator display. This routine will loop back to "RUN DATA" select position when the fuze identifier is moved to any number other than zero.

5.0 INSTALLATION INSTRUCTIONS

1. Remove all packing material from Welder frame and Computer frame. Remove side panels and remove all wood members used for support during shipment.

2. Place the welder frame on the left of the computer frame. Separate the two frames by approximately two feet.

3. Unpack the HP 9871A printer and install this unit on the top of the computer frame to the right.

4. Unpack Hewlett Packard 9825A computer and install this unit on the top of the computer frame to the left.

5. Unwrap the two power cords coming from the power distribution panel of the computer frame. Connect each tagged plug to its respective power receptacle on the H.P. 9825A and H.P. 9871A.

6. Connect the "address 6" 98032 plug interface from the 9825A computer and 9871A printer. Use slot one of the computer.

7. Connect the 9878/10 expander plug interface to the slot 2 of the 9825A computer.

8. Connect the air line input to an 80 psi air source. (Welder Console)

9. Connect the cable with the HP 9834 plug interface that is connected to the welder console to slot 7 of the 9878A 1/0.

10. Connect the Elco connectors numbers 3, 4 and 5 to the logic interface panel on the welder console.

11. Connect the "remote" connector from the rear of the 1508B visicorder to "remote visicorder" jack on the logic interface panel on the welder console. Use the cable marked "remote visicorder cable."

12. Connect the three galvanometer cables connected to the rear of the Mark VI beat rate amplitude chassis in the welder console to the galvanometer inputs of 1508B visicorder in the computer console. The plugs should be plugged into the 1, 3, and 5 galvanometer positions.

13. Connect the Anorad Motor Cable on the welder Console to the Anorad electronic control unit on the computer console.

14. With the circuit breakers in the "OFF" condition, connect the AC power input through its associated cable to a power source of 117 Volts, 60 hertz at 20 amperes.

15. Verify that the correct time is being displayed on the H.P. digital clock Model 59309A. To reset time, refer to Hewlett Packard Digital Clock model 59309A technical manual H.P. P/N 59309-90004.

16. Using a carpenter's level, set the levelers on both consoles to optimum heights and tighten in position.

6.0 OPERATION INSTRUCTIONS

1. Put the circuit breaker on Welder mainframe to the ON position (Both, the white and red lights should light).

2. Insert a "marked" program and data casette cartridge into the 9825A computer tape transport mechanism. Push the POWER switch to the ON position. The 9825A computer should load automatically and the message "0-RUN, 1-DATA" should be displayed on the LED readout of the computer. After a short delay, the Anorad electronics should turn on automatically. The POWER switch will light at this time.

3. Insert "0", then press "CONTINUE". Set some final numbers on the fuze number switches.

4. Insert a fuze into the table fixture.

5. Close the safety cover and the regulation operation will start automatically.

6. After the automatic cycle, a COMPLETE lamp will light and the fuze may be removed after the safety cover is opened. A REJECT lamp lights if the fuze is unable to meet the acceptance criteria and the rejected fuze separated from the accepted fuzes.

7. In the normal mode of operation, fuze data storage will occur after the 200th fuze. A "PUT FILE #" message will appear. Select a file number starting with zero (press zero, then continue on the computer) and after the data have been stored, "0-RUN, 1-DATA" will appear again for a new lot of 200 fuzes. fuzes. Press "0" again, then continue to start the program again.

8. Create a new program and data casette cartridge, using a blank cartridge, as follows:

a. Turn the Regulation Machine off by pressing the POWER OFF switch on the Power Distribution Panel.

b. Verify that an original program and data casette is inserted in the tape transport mechanism correctly.

c. After at least 20 seconds, re-apply power to the Regulation Machine by pressing the POWER ON switch. The tape should load the program memory automatically.

d. The message "0-RUN, 1-DATA" should be displayed on the LED readout of the computer.

e. Write in the number "712" to load the special function keys of the computer and press the "CONTINUE" switch. After the loading completes itself, the message "0-RUN, 1-DATA" will again appear.

f. Remove the original program tape and insert a new unmarked blank casette into the tape transport mechanism.

g. Write in the number "710" and press the CONTINUE switch. Completion of the storage operation will be indicated by the reappearance of the "0-RUN, 1 DATA" display message.

h. The new tape now has the original program and is ready to receive data after a 200-unit operation. Each tape is capable of storing data from 2000 fuzes in 10 separate files from File No. 0 (zero) to File No. 9.

7.0 ACCEPTANCE TEST PROCEDURES

To facilitate proper acceptability for the Automatic Welding Regulation machine this acceptance test procedure has been written, outlining suitable criteria for contractually required performance.

1. Connect the regulation machine to a source of 117V ± 10%, 20 ampere, single-phase power.

2. Observe that power is available in the OFF position by verifying on the welder frame that:

2.1 The 110 volt primary source red light is on.

2.2 The 5909A Hewlett-Packard Digital Clock is displaying the correct time.

3. Place the circuit breaker on the welder frame to the "ON" position.

4. Verify that the White "OFF" light is on.

5. Press the "ON" button.

5.1 Verify a yellow light appears on the "ON" switch and the white light goes out on the "OFF" button.

5.2 After a few seconds verify that the 9825 Hewlett-Packard computer calculator reads "0-RUN 1-DATA" on its LED display readout after the program tape loads.

5.3 After a delay of from 10 to 60 seconds, the power light on the Anorad driver chassis on the computer frame should light.

6. Insert the number 712 and press the CONTINUE switch.

7. After a few seconds press the "LAMPS" switch. Both "Complete" and "REJECT" lamps should light. Press "RESET" and the lamps should go out. This test indicates that the special functions have been loaded.

8. Press "STOP" and then special function key "RUN 2".

9. Press "CONTINUE". The "0-RUN 1-DATA" message should appear.

10. Insert the number "2" and press "CONTINUE".

11. Enter "1" for the "STARTING RUN".

12. Enter "5" for the "FINISH RUN STORED".

13. Press "CONTINUE". The computer will now enable testing of five units and then store the data.

14. Press zero for "RUN", then press "CONTINUE".

15. Obtain five unregulated fuzes.

16. Open safety hood.

17. Insert unit one in fixture, insert unit or lot number on digital switches.

18. Close safety hood and automatic regulation should begin.

19. When "COMPLETE" or "REJECT" light appears, open hood and run next unit until all five have been regulated.

20. After the fifth unit has been run, a "PUT FILE #" message should appear

21. Press "7" and then press "CONTINUE".

22. The yellow tape operation light should light and program stored message should appear together with a repetitive "beep."

23. The computer should recycle and be ready for the next lot of five units.

24. To check a particular file and print the data, do the following:

24.1 Push the "STOP" button

24.2 Push the "RUN 2" special function key

24.3 Push the "CONTINUE" button; the "0-RUN 1 DATA" message should appear

24.4 Enter "1" on the keyboard

24.5 Press "CONTINUE"

24.6 A "GET FILE #" message should appear

24.7 Pick the file number by inserting "7".

24.8 Push "CONTINUE" and the message, "START RUN", should appear after loading file 7.

24.9 Insert "1" into the keyboard, press "CONTINUE"

24.10 A "FINISH RUN" message should appear

24.11 Insert "5" into the keyboard, press "CONTINUE"

24.12 The 9871A printer should print the contents of File 7 from run 1 to run 5

8.0 CALIBRATION PROCEDURE

Calibration procedures should be accomplished on the following three items:

Mark VI Beat Rate amplitude system

Sonobond Sonoweld Ultrasonic Spot Welder Model M600

Hewlett Packard - Model 9825A Computer Calculator

SUGGESTED LIST OF CALIBRATION EQUIPMENT

Hewlett Packard 5245M Electronic Counter

Hewlett Packard 3320A Frequency Synthesizer

Commercial Quality Cassette tape recorder - playback

Bulova Standard 577 clock and Running Fixture

120 degree Clock Signal tape

8.1 AMPLITUDE CALIBRATION FOR MARK VI

WARNING

THIS MACHINE USES HAZARDOUS ELECTRICAL VOLTAGES AND MECHANICAL FORCES. MAINTENANCE OF THIS MACHINE SHOULD BE ADEQUATELY SUPERVISED BY PERSONNEL KNOWLEDGEABLE IN ELECTRICAL AND PNEUMATIC SAFETY DISCIPLINES

1. Disconnect cable on Connector J1A located on rear of Mark VI.

2. Connect cable from "LINE OUT" jack of tape recorder to J1A (recorder used was "AMPEXMICRO 24" cassette).

3. Put level (volume) control to minimum and tone control to maximum treble on tape recorder.

4. TEKTRONIX Oscilloscope on front of console should be set as follows: POWER switch pulled out, MS button pushed IN, x10 and x100 buttons both out, 100MV button out, IV button in and the INT. EXT. switch to EXT. The scope should now display noise.

5. Set recorder to play positionand slowly increase level. A wave pattern will appear and as level is increased. Bottom of wave pattern will saturate (clip). Increase level until top of entire wave pattern just saturates, and no further.

6. On Board 300 located on chassis below the Mark VI, adjust the 100K resistor for a reading of 120 on the digital voltmeter on front of console. (Note: The 100K resistor is the potentiometer furthest from the rear panel)

7. Disconnect tape recorder from J1A and reconnect original cable.

   NOTE: A tape is generated by driving a hair spring in a closed loop set-up using a vibrator fixture and Mark III frequency meter with power amplifier. The main spring is driven to exactly $\neq$ 120° by use of precision reference lines, a stroboscope and a magnifier. The resultant electrical signal derived from the associated pick-up optics and amplifier is recorded on a tape for future calibration useage.

Performance verification of the HP 9825 calculator system is outlined in the "Hewlett-Packard 9825A Calculator System Test Booklet" (Part number 09825-90031). The System Test Cartridge (Part number 0985-90035 contains the necessary programs to implement performance tests on the calculator and Peripheral equipment associated with the calculator programming and monitoring system.

Operation and calibration procedures for the Sonobond Sonoweld Ultrasonic Spot Welder Model 600 are outlined in the Sonobond Manual #76-2A.

9.0 MAINTENANCE PROCEDURES, TROUBLE SHOOTING PROCEDURES, LOCATION OF PROBES

9.1 DAILY

The Photo-optic pick-up and illumination source should be cleaned with freon and inspected.

The welder anvils should be inspected for wear and cracks. The alignment of anvils should be checked.

The air pressure indicators should be checked for correct pressure.

Recorder paper should be determined to be adequate and properly loaded in the 9875 calculator, the 9871A Printer and the 1508B Visicorder.

The Anorad table should yield a read out of 0000 at the home position. The green light should light and not blink on and off greater than a rate of two cycles per second.

9.2 WEEKLY

Check the Visicorder lamp by observing the recorded trace contrast.

Inspect all air cleaners for obstructions.

A general external cleaning of computer keyboard, printer, and welding operating area should be done.

The fixture and high resolution table positioner should be oiled and greased.

All cable connectors should be checked to ensure good mechanical and electrical connection.

9.3 MONTHLY

Clean or replaced all air filters on both consoles, computer, visicorder, and table positioner electronics.

A check of the time accuracy of the digital clock should be made.

9.4 SIX MONTHS

The nine-bolt internal digital clock battery should be changed.

10.0 LIST OF COMPONENT MANUALS AND SOFTWARE

Hewlett-Packard 9825A Calculator Computer System

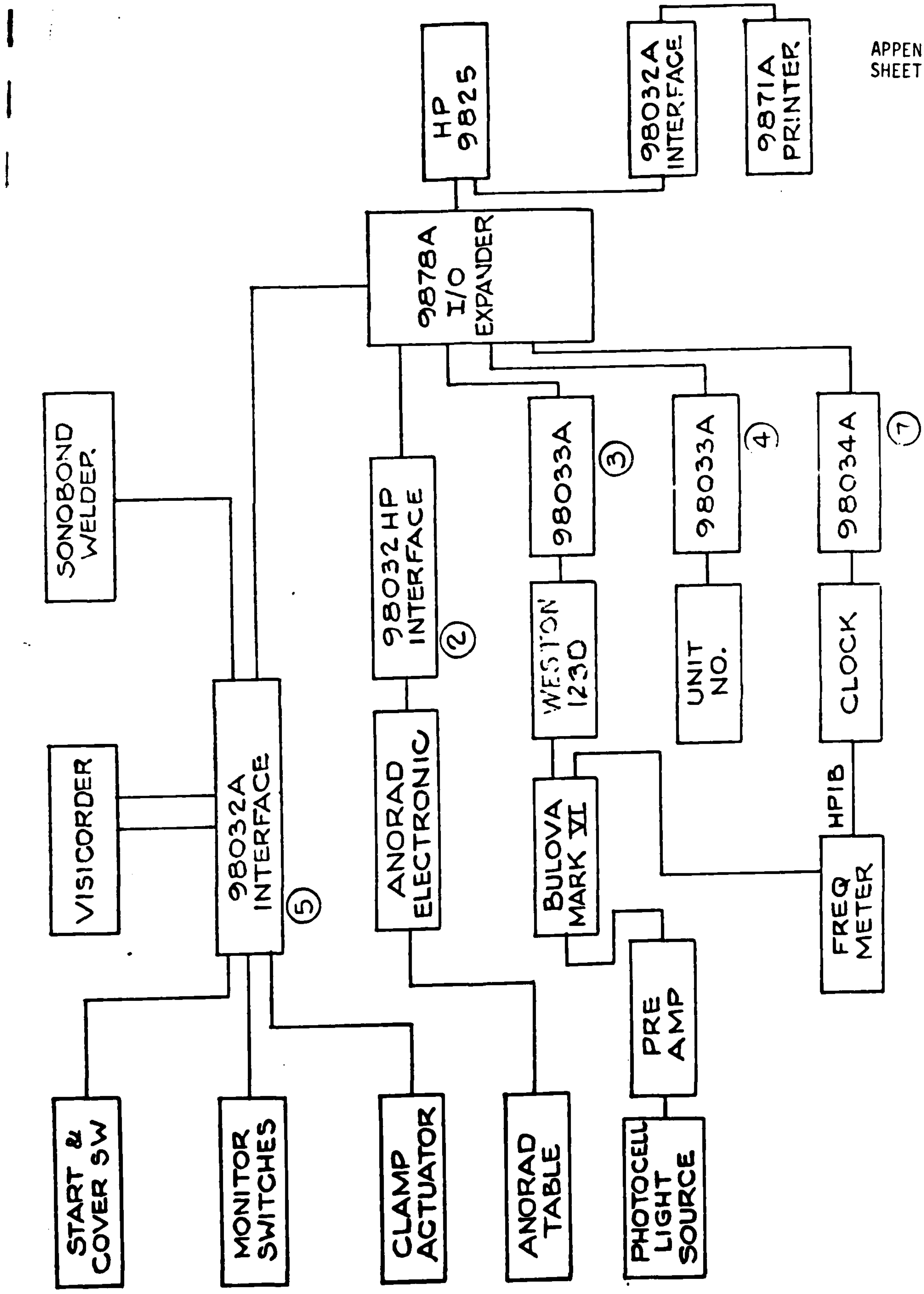
1. Hewlett-Packard 9825A Calculator System Test Booklet P/N 09825-90031
2. Hewlett-Packard 9825A Calculator Quick Reference Guide P/N 09825-90011
3. Hewlett-Packard 9825A Calculator Operating and Programming P/N 09825-90000
4. Hewlett-Packard 9825A Calculator Advanced Programming P/N 09825-90021
5. Hewlett-Packard 9825A Calculator General I/0 Programming P/N 09825-90024
6. Hewlett-Packard 9825A Calculator String Variable Programming P/N 09825-90020
7. Hewlett-Packard 9825A Calculator Extended I/0 Programming P/N 0925-90025
8. Hewlett-Packard 9825A Calculator 98032A Option 71 Interface Printer Opeating Note P/N 09825-90045
9. Hewlett-Packard 9871A Calculator Printer Operating & Service Manual P/N 09871-90030
10. Hewlett-Packard 9878A I/0 Expander Installation and Service Manual P/N 9878-90000
11. Hewlett Packard Digital Clock Model 59309A P/N S9309-90004
12. Hewlett Packard 98034A HP-1B Interface Installation and Service Manual P/N 98034-90000
13. Hewlett Packard 98033A BCD Interface Installation and Service Manual P/N 98033-90000
14. Hewlett Packard 98032A 16 set Interface Installation and Service Manual P/N 98032-90000
15. Hewlett Packard General Utility Routines P/N 09825-10001 Rev. E
16. Hewlett Packard Software P/N 9282-0563
17. Hewlett Packard Data Cartridge (Blank) P/N 9162-0061

18. Hewlett Packard 9825A System Test Cartridge P/N 09825-90035 9825A and peripherals
19. Hewlett Packard 9825A General Utility Routine Cartridge P/N 09825-10004
20. Hewlett Packard 5300 Measurement Systems Binder Stock Number 05300-90030
21. Hewlett Packard Operating and Service Manual 5300B & Battery Pack 5310 P/N 05300-90028
22. Hewlett Packard Operating & Service Manual High Resolution Counter 5307A P/N 05307-90004
23. Hewlett Packard Operating & Service Manual, ASCII Interface 5312A P/N 05312-90004
24. Tektronics SC501 Oscilliscope P/N 070-1700-00
25. Tektronics Power Module TM501 P/N 070-1304-00
26. Datel Systems Inc. DM1100 Bulletin MIKEN 10608
27. Anorad Corp. Model 133 Single Axis positioning system
    C3169 Wire Wrap Interface/Limit Board
    C1988 6 digit display & sign schematic
    C1665-1 Analog section absolute axis 013B2
    D1545-1 Counter Section Absolute Axis 013BZ
    D1656-1 1656-1 Subtractor section absolute axis 013B2
    C2128 5X encoder logic absolute axis 013B2
    C2452-00 Motor Driver Card Schematic
    A3173 Simulated Computer Test Box Fixture
28. Sonoweld Ultrasonic Spot Welder for Model M600 Manual 76-2A
29. Bulova Systems Instruments Mark VI Service Manual & instructions 675-01
30. Bulova Systems Instruments System Schematics P675
31. Honeywell Model 1508B Visicorder Oscillograph Technical Manual P/N 16775842-001C

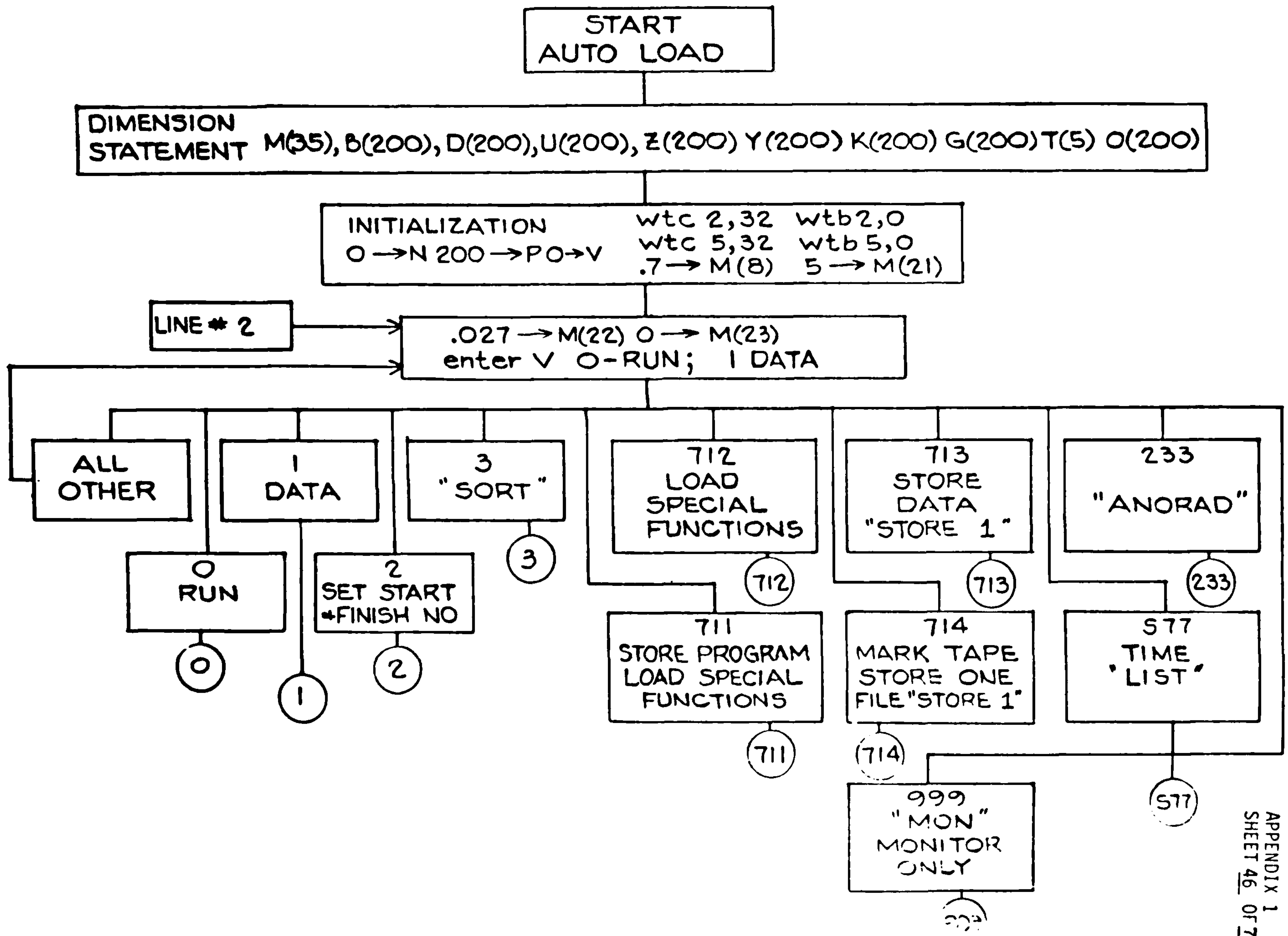
11.0 PROGRAM FLOW CHART

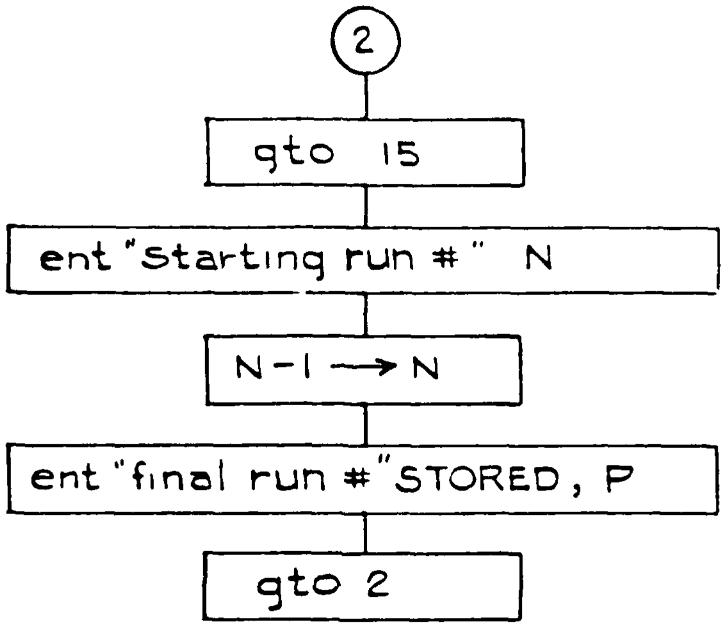
11.1 Automatic Welding Machine

Following is a Program Flow Chart for the Automatic Welding Machine.

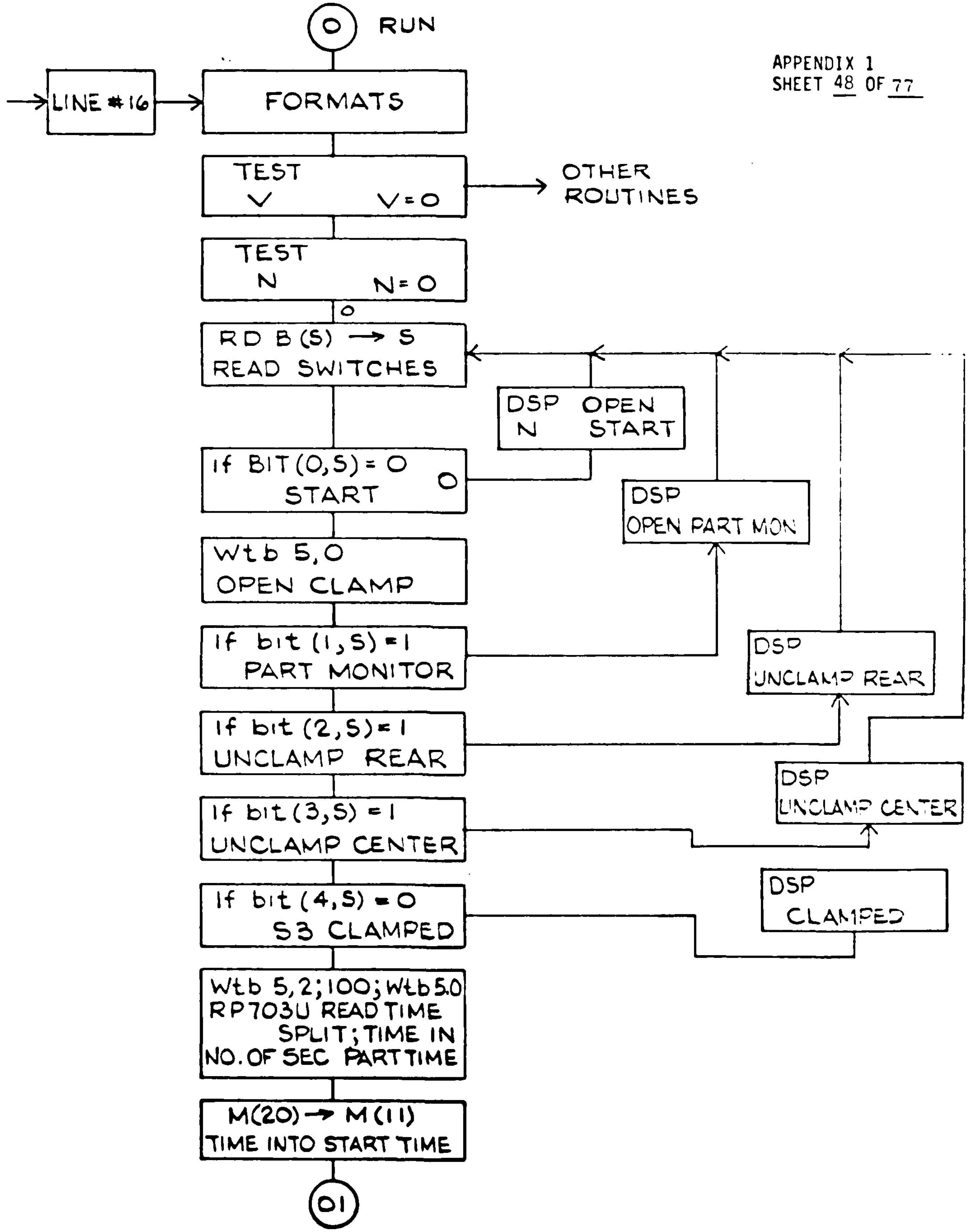


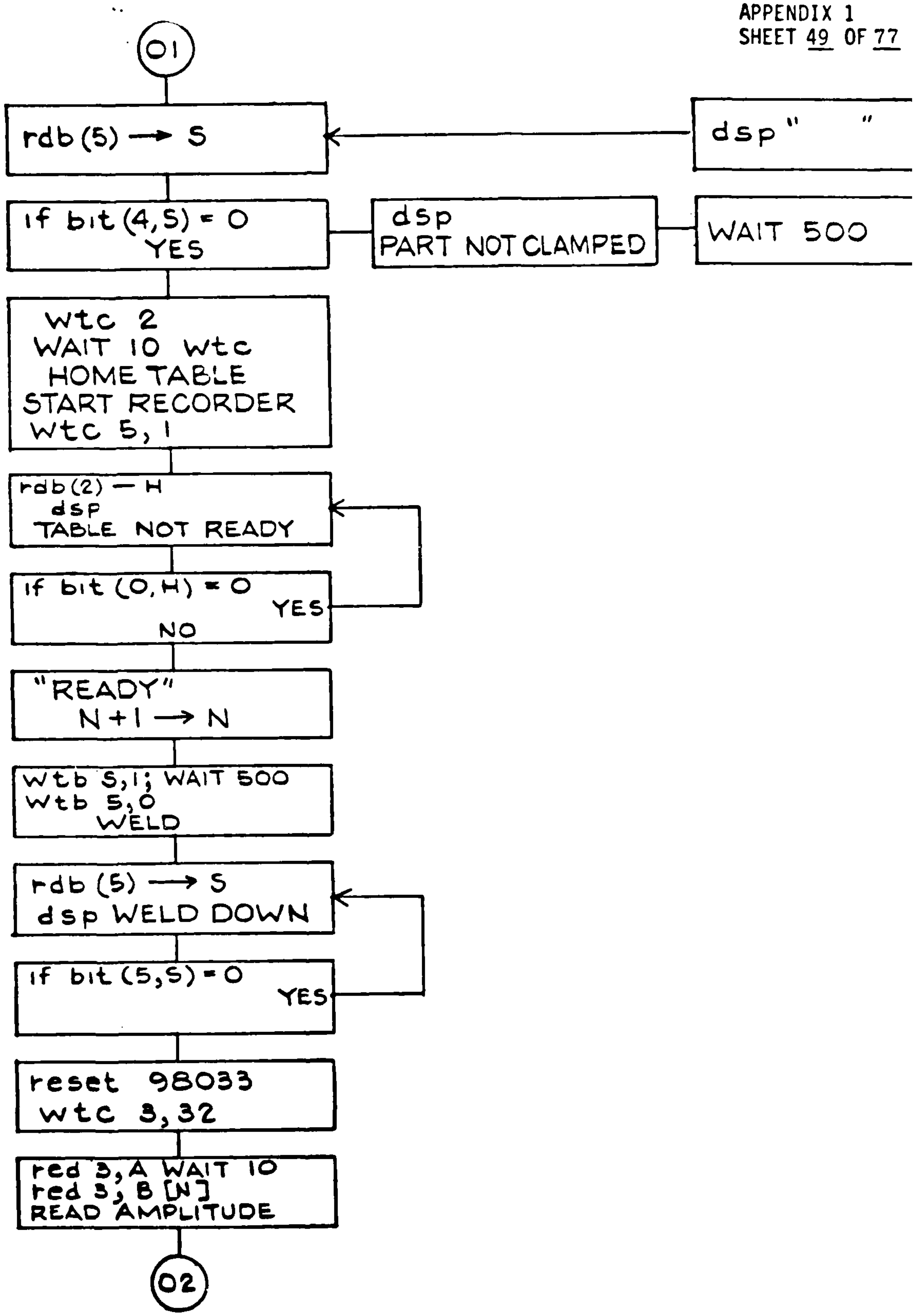
AUTOMATIC WELDING REGULATION MACHINE

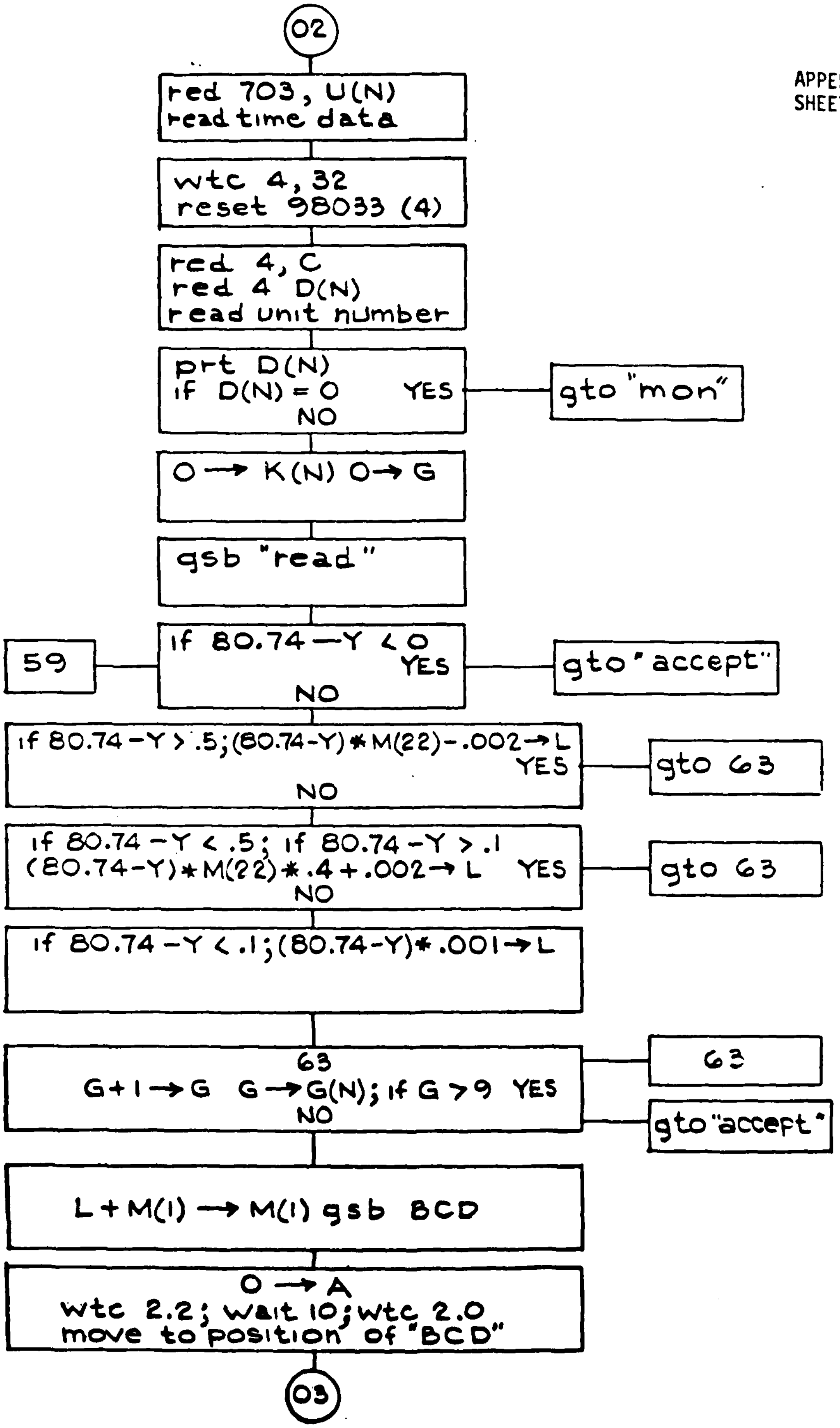

START
AUTO LOAD
DIMENSION
STATEMENT M(35), B(200), D(200), U(200), Z(200) Y(200) K(200) G(200) T(5) O(200)
INITIALIZATION
O → N 200 → PO → V
wtc 2,32 wtb2,0
wtc 5,32 wtb 5,0
.7 → M(8) 5 → M(21)
LINE # 2
.027 → M(22) O → M(23)
enter V O-RUN; 1 DATA
ALL OTHER
O RUN
1 DATA
2 SET START +FINISH NO
3 "SORT"
712 LOAD SPECIAL FUNCTIONS
711 STORE PROGRAM LOAD SPECIAL FUNCTIONS
713 STORE DATA "STORE 1"
714 MARK TAPE STORE ONE FILE "STORE 1"
233 "ANORAD"
577 TIME 'LIST'
999 "MON" MONITOR ONLY
0
1
2
3
712
711
713
714
233
577

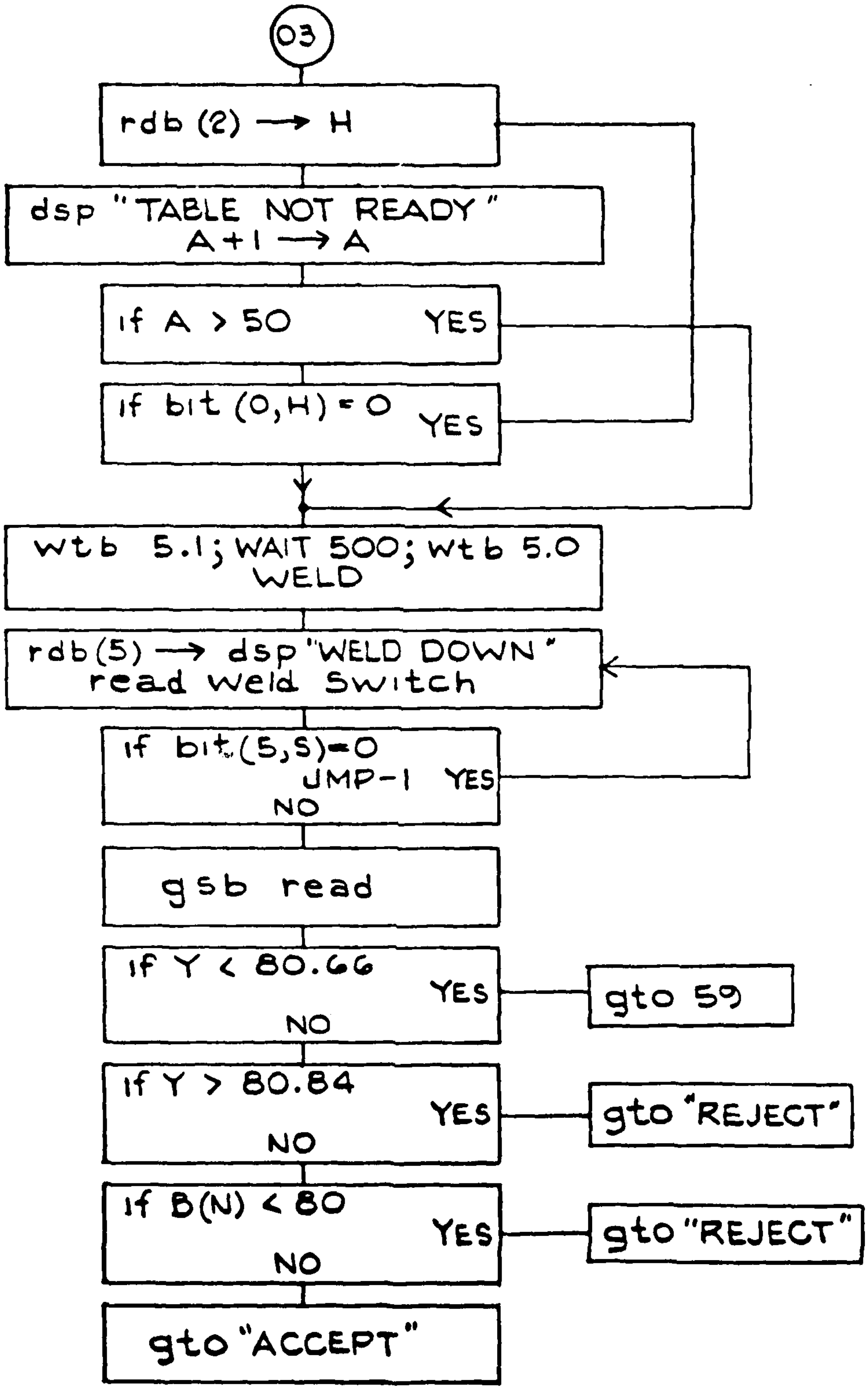

2
gto 15
ent "starting run #" N
N-1 → N
ent "final run #"STORED, P
gto 2

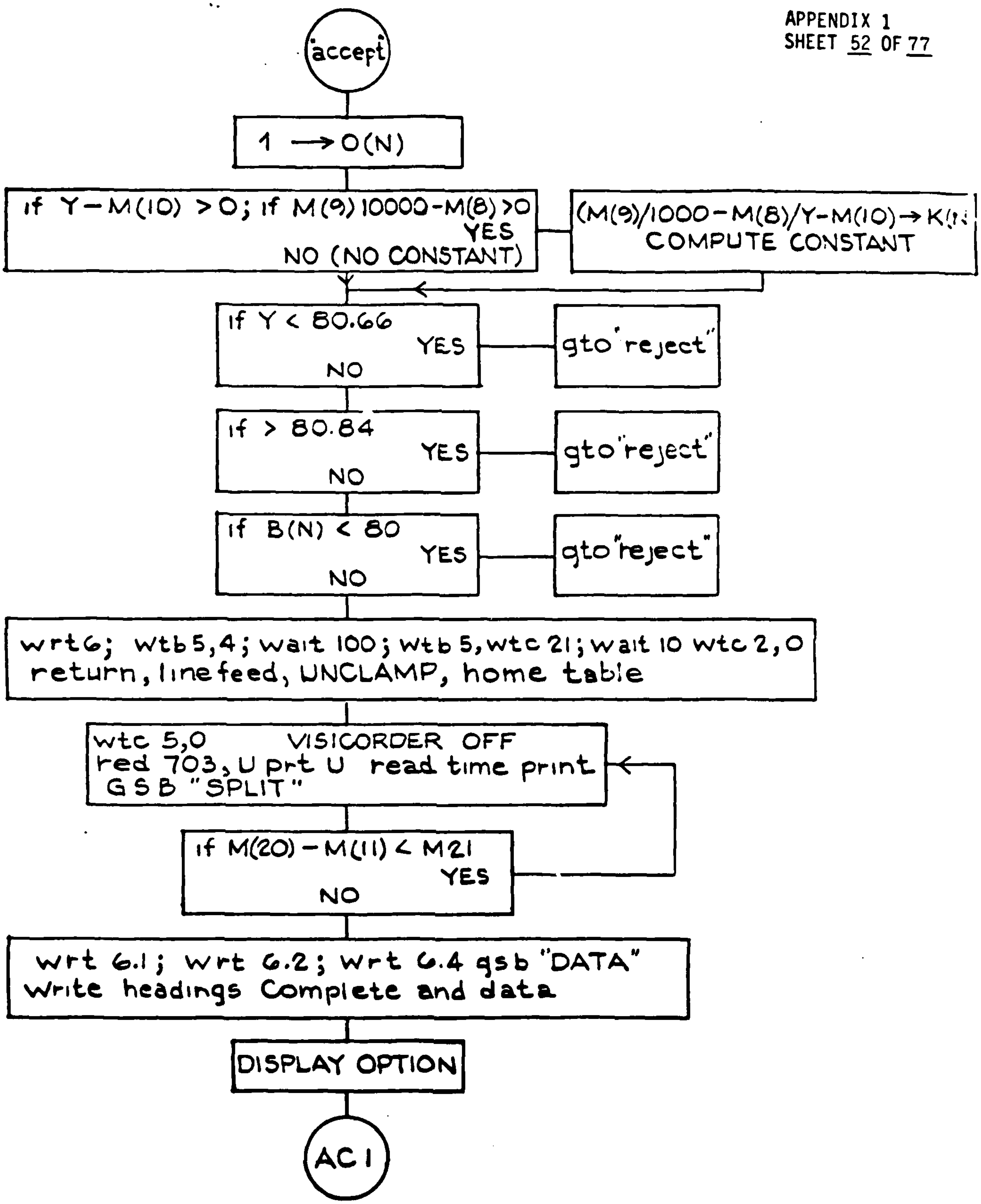
APPENDIX 1
SHEET 48 OF 77

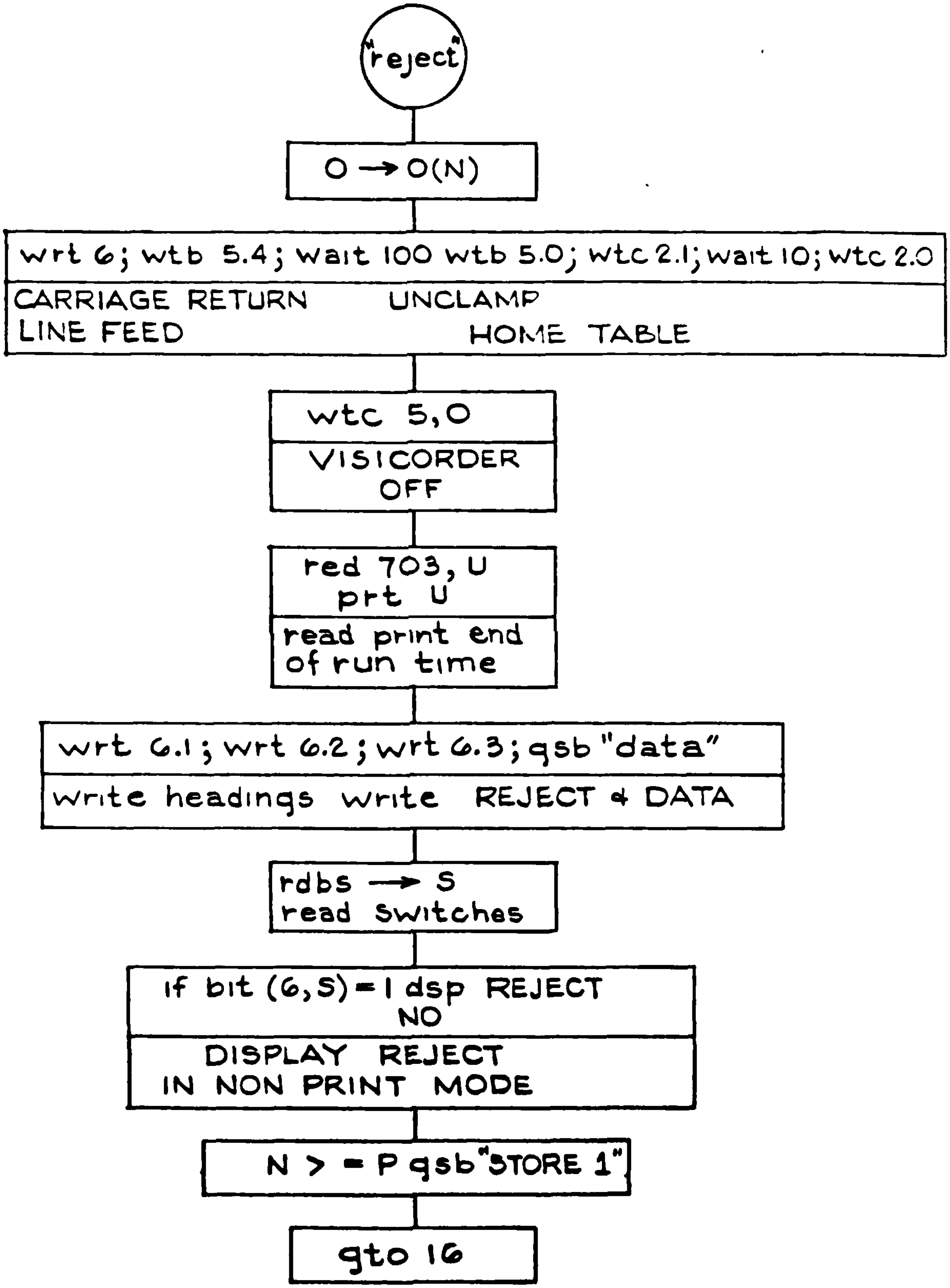


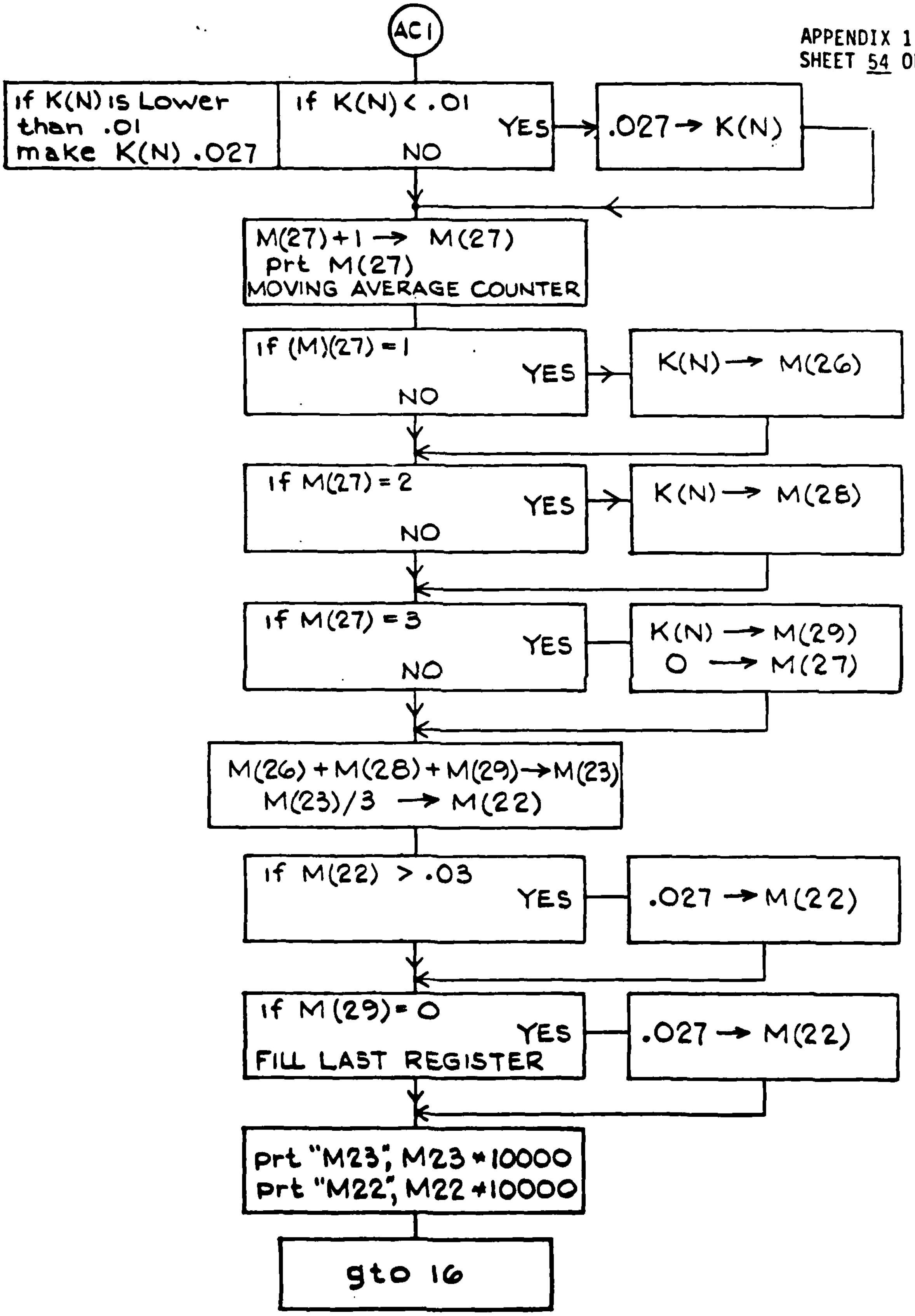

01
rdb (5) → S
dsp " "
if bit (4,S) = 0
YES
dsp
PART NOT CLAMPED
WAIT 500
wtc 2
WAIT 10 wtc
HOME TABLE
START RECORDER
wtc 5, 1
rdb (2) — H
dsp
TABLE NOT READY
if bit (0, H) = 0
YES
NO
"READY"
N + 1 → N
wtb 5,1; WAIT 500
wtb 5,0
WELD
rdb (5) → S
dsp WELD DOWN
if bit (5,S) = 0
YES
reset 98033
wtc 3, 32
red 3, A WAIT 10
red 3, B [N]
READ AMPLITUDE
02

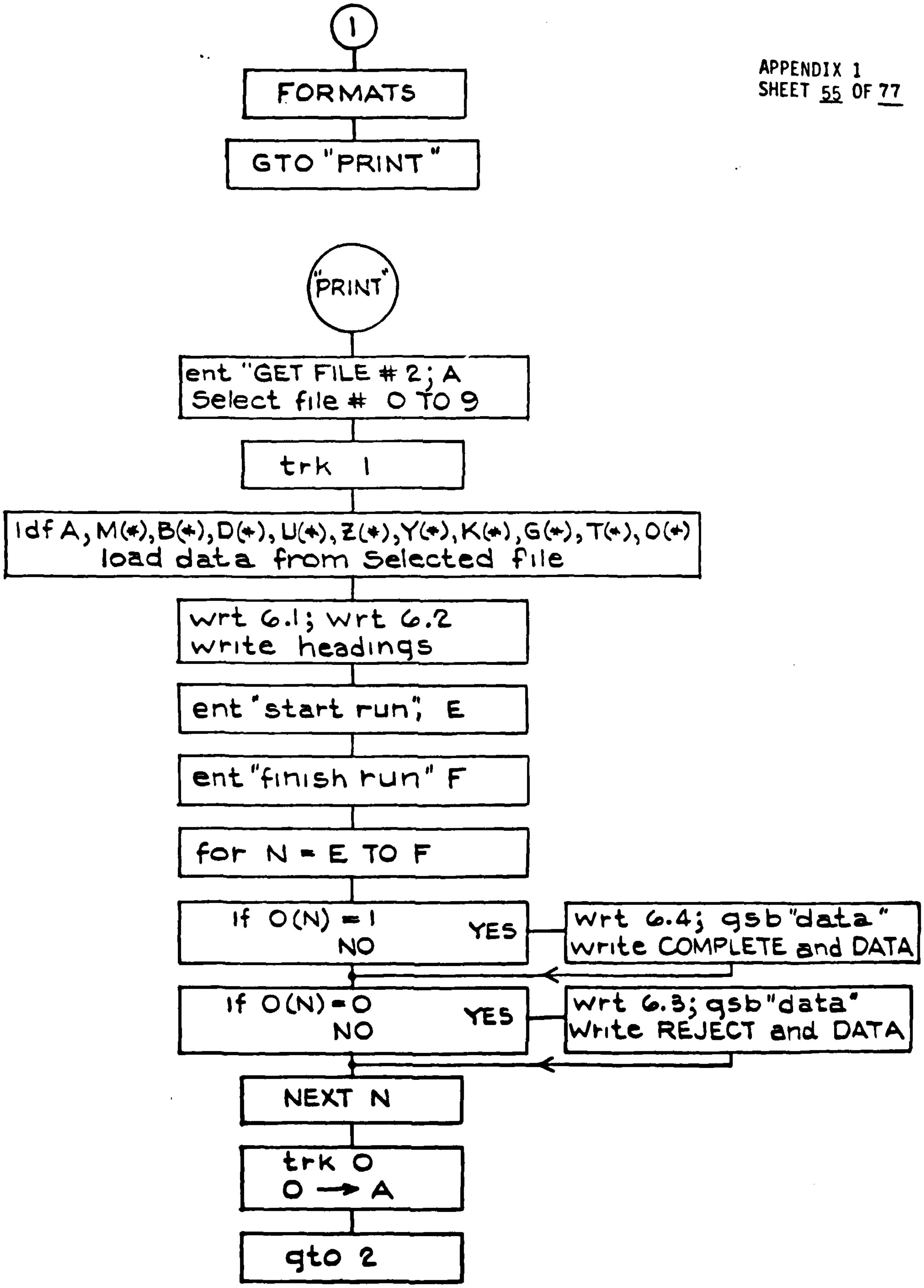

02
red 703, U(N)
read time data
wtc 4, 32
reset 98033 (4)
red 4, C
red 4 D(N)
read unit number
prt D(N)
if D(N) = 0 YES
NO
gto "mon"
0 → K(N) 0 → G
gsb "read"
if 80.74 — Y < 0
YES
NO
59
gto "accept"
if 80.74 - Y > .5; (80.74-Y) * M(22) - .002 → L
YES
NO
gto 63
if 80.74 - Y < .5; if 80.74 - Y > .1
(80.74-Y) * M(22) * .4 + .002 → L YES
NO
gto 63
if 80.74 - Y < .1; (80.74-Y) * .001 → L
63
G+1 → G G → G(N); if G > 9 YES
NO
63
gto "accept"
L + M(1) → M(1) gsb BCD
0 → A
wtc 2.2; wait 10; wtc 2.0
move to position of "BCD"
03

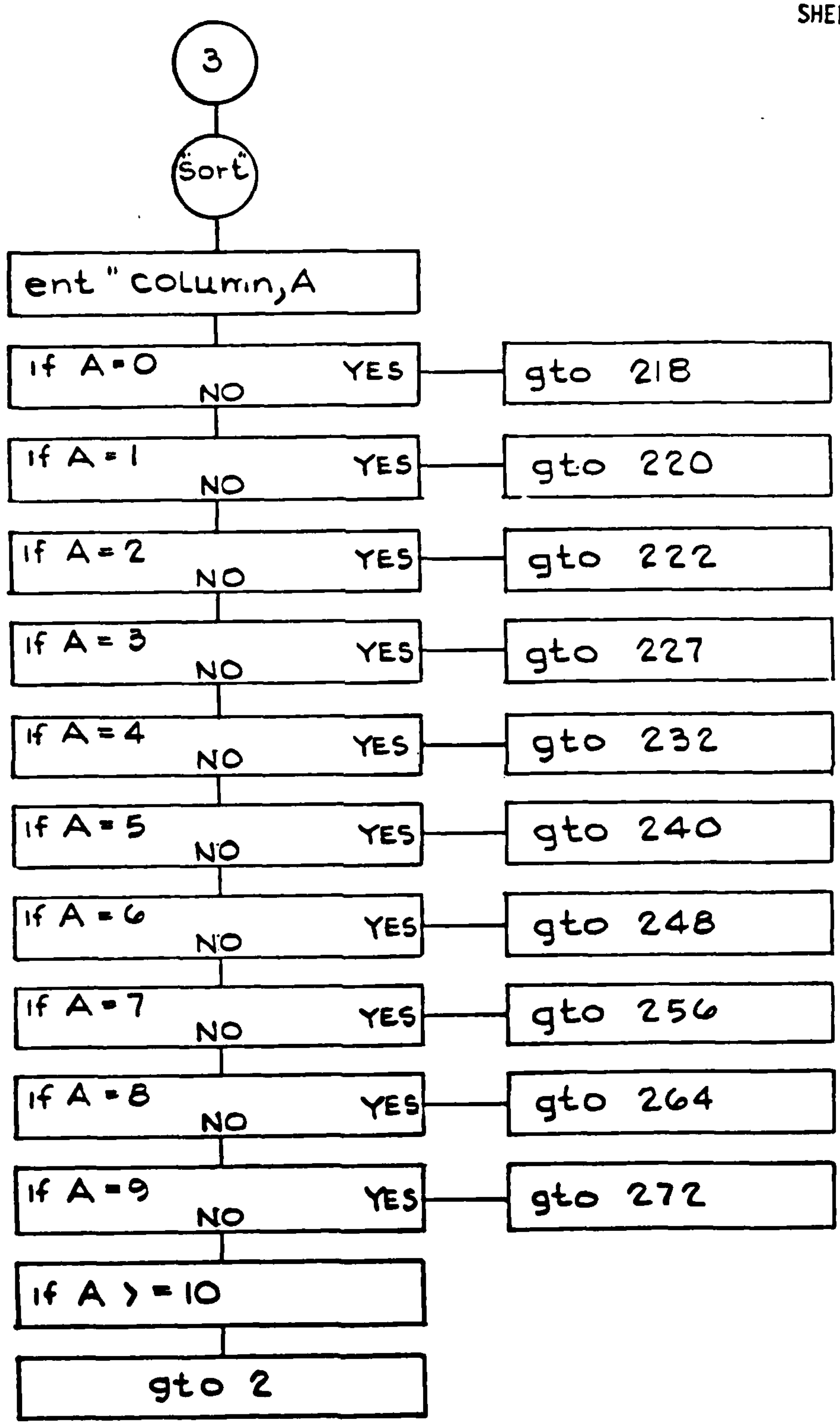

03
rdb (2) → H
dsp "TABLE NOT READY"
A+1 → A
if A > 50
YES
if bit (0,H) = 0
YES
wtb 5.1; WAIT 500; wtb 5.0
WELD
rdb(5) → dsp "WELD DOWN"
read Weld Switch
if bit (5,S)=0
JMP-1
YES
NO
gsb read
if Y < 80.66
YES
NO
gto 59
if Y > 80.84
YES
NO
gto "REJECT"
if B(N) < 80
YES
NO
gto "REJECT"
gto "ACCEPT"


accept
1 → O(N)
if Y−M(10) > 0; if M(9) 10000−M(8) > 0
YES
NO (NO CONSTANT)
(M(9)/1000−M(8)/Y−M(10) → K(
COMPUTE CONSTANT
if Y < 80.66
YES
NO
gto "reject"
if > 80.84
YES
NO
gto "reject"
if B(N) < 80
YES
NO
gto "reject"
wrt6; wtb5,4; wait 100; wtb 5, wtc 21; wait 10 wtc 2,0
return, line feed, UNCLAMP, home table
wtc 5,0 VISICORDER OFF
red 703, U prt U read time print
GSB "SPLIT"
if M(20) − M(11) < M21
YES
NO
wrt 6.1; wrt 6.2; wrt 6.4 gsb "DATA"
Write headings Complete and data
DISPLAY OPTION
AC1

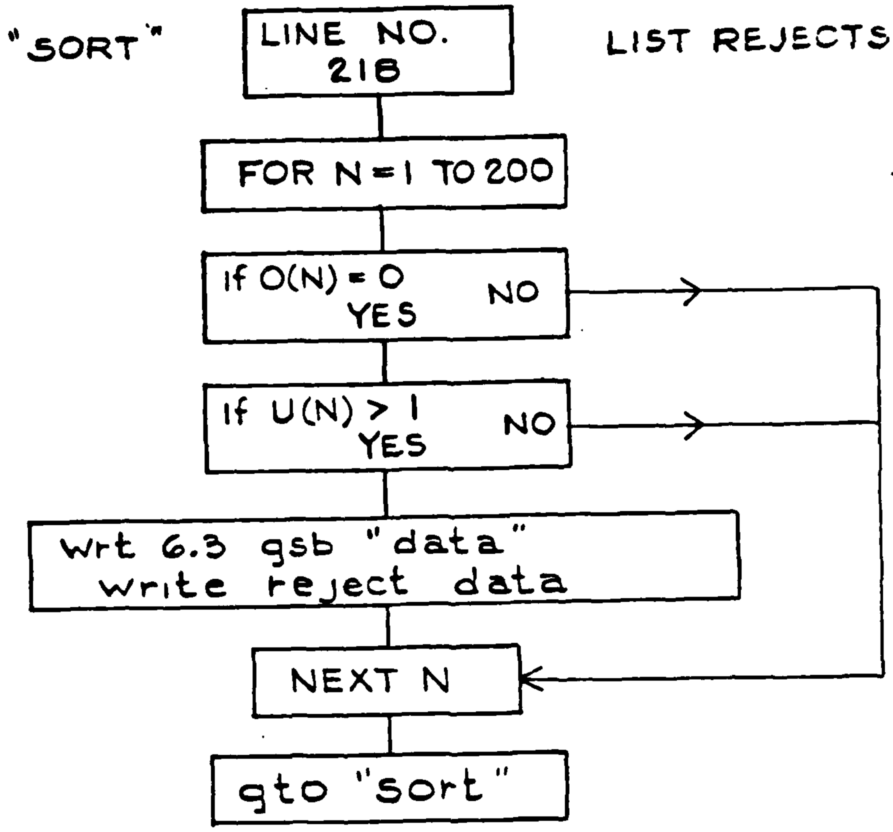

"reject"
O → O(N)
wrt 6; wtb 5.4; wait 100 wtb 5.0; wtc 2.1; wait 10; wtc 2.0
CARRIAGE RETURN UNCLAMP
LINE FEED HOME TABLE
wtc 5,0
VISICORDER OFF
red 703, U
prt U
read print end of run time
wrt 6.1; wrt 6.2; wrt 6.3; gsb "data"
write headings write REJECT & DATA
rdbs → S
read switches
if bit (6,S) = 1 dsp REJECT
NO
DISPLAY REJECT IN NON PRINT MODE
N > = P gsb "STORE 1"
gto 16


AC1
if K(N) is Lower than .01 make K(N) .027
if K(N) < .01
YES
NO
.027 → K(N)
M(27)+1 → M(27)
prt M(27)
MOVING AVERAGE COUNTER
if (M)(27) = 1
YES
NO
K(N) → M(26)
if M(27) = 2
YES
NO
K(N) → M(28)
if M(27) = 3
YES
NO
K(N) → M(29)
0 → M(27)
M(26) + M(28) + M(29) → M(23)
M(23)/3 → M(22)
if M(22) > .03
YES
.027 → M(22)
if M(29) = 0
YES
FILL LAST REGISTER
.027 → M(22)
prt "M23", M23 * 10000
prt "M22", M22 * 10000
gto 16

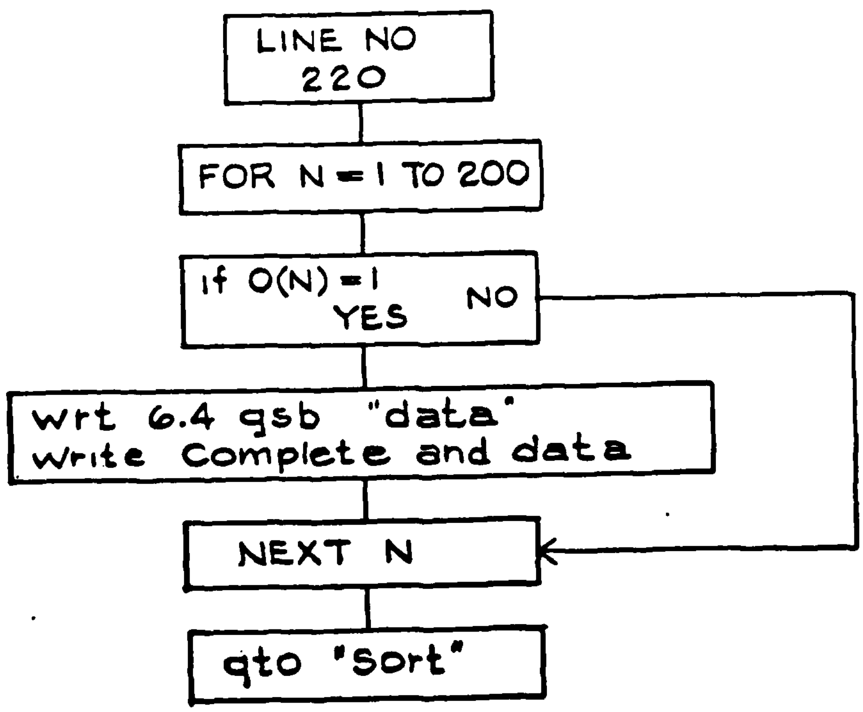

1
FORMATS
GTO "PRINT"
"PRINT"
ent "GET FILE # 2; A
Select file # 0 TO 9
trk 1
ldf A, M(*), B(*), D(*), U(*), Z(*), Y(*), K(*), G(*), T(*), O(*)
load data from Selected file
wrt 6.1; wrt 6.2
write headings
ent "start run", E
ent "finish run" F
for N = E TO F
If O(N) = 1
YES
NO
wrt 6.4; gsb "data"
write COMPLETE and DATA
If O(N) = 0
YES
NO
wrt 6.3; gsb "data"
Write REJECT and DATA
NEXT N
trk 0
0 → A
gto 2

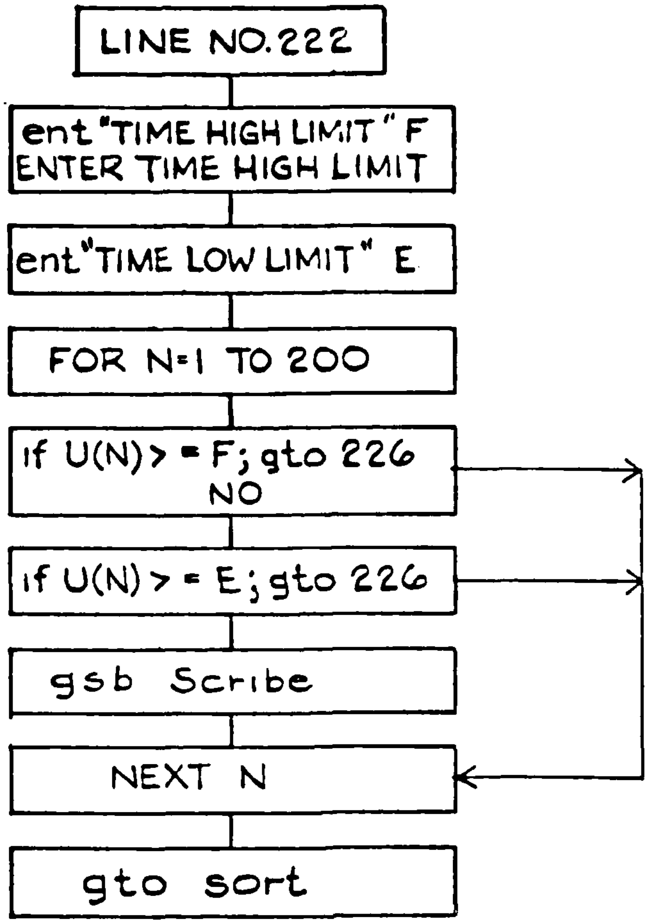

3
"Sort"
ent "column,A
if A=0
YES
NO
gto 218
if A=1
YES
NO
gto 220
if A=2
YES
NO
gto 222
if A=3
YES
NO
gto 227
if A=4
YES
NO
gto 232
if A=5
YES
NO
gto 240
if A=6
YES
NO
gto 248
if A=7
YES
NO
gto 256
if A=8
YES
NO
gto 264
if A=9
YES
NO
gto 272
if A >=10
gto 2

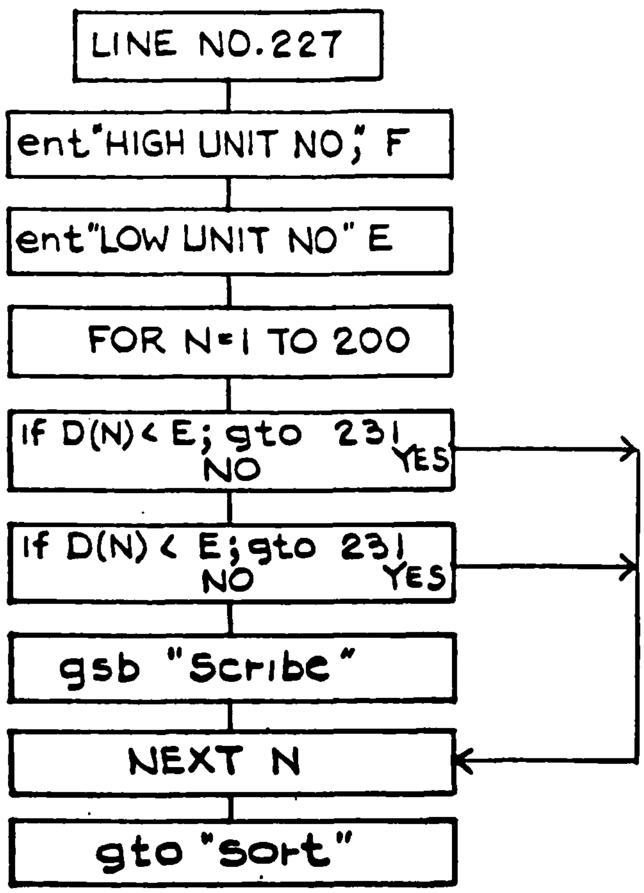
LIST REJECTS

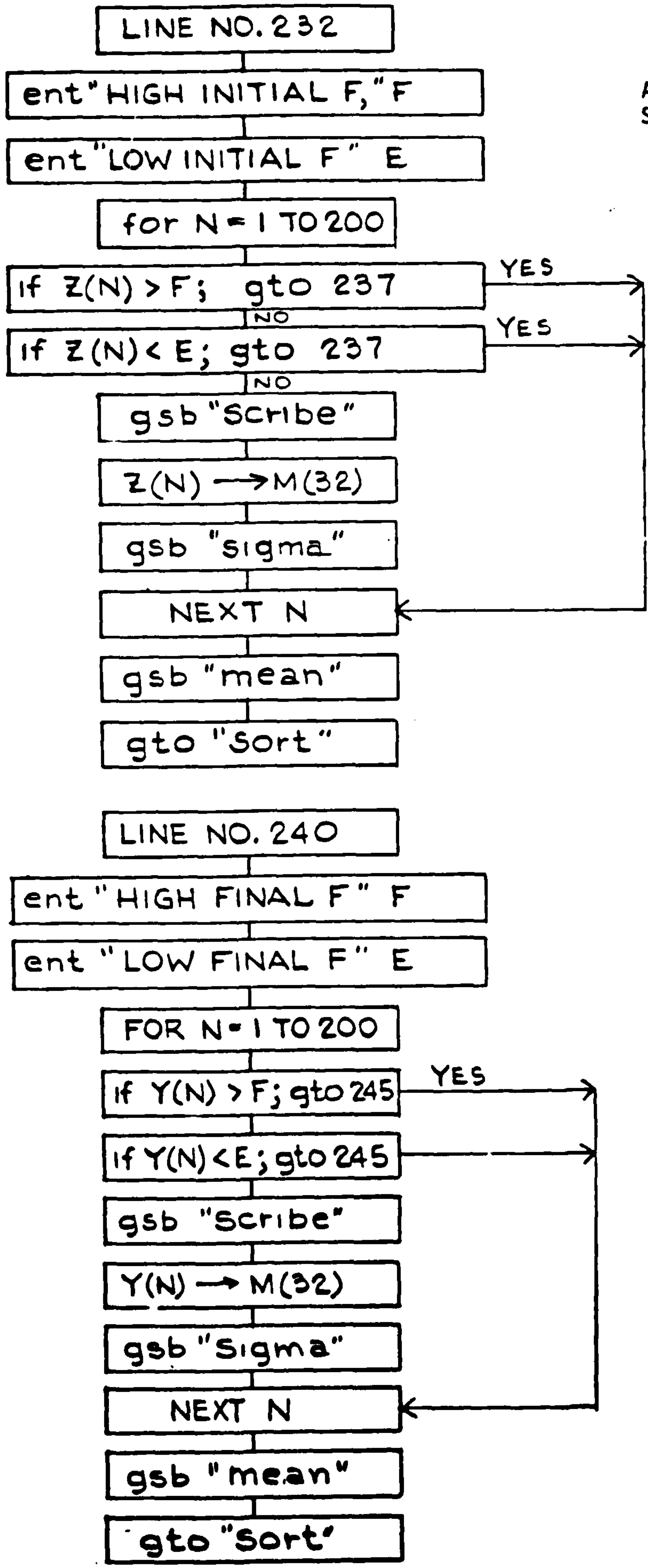


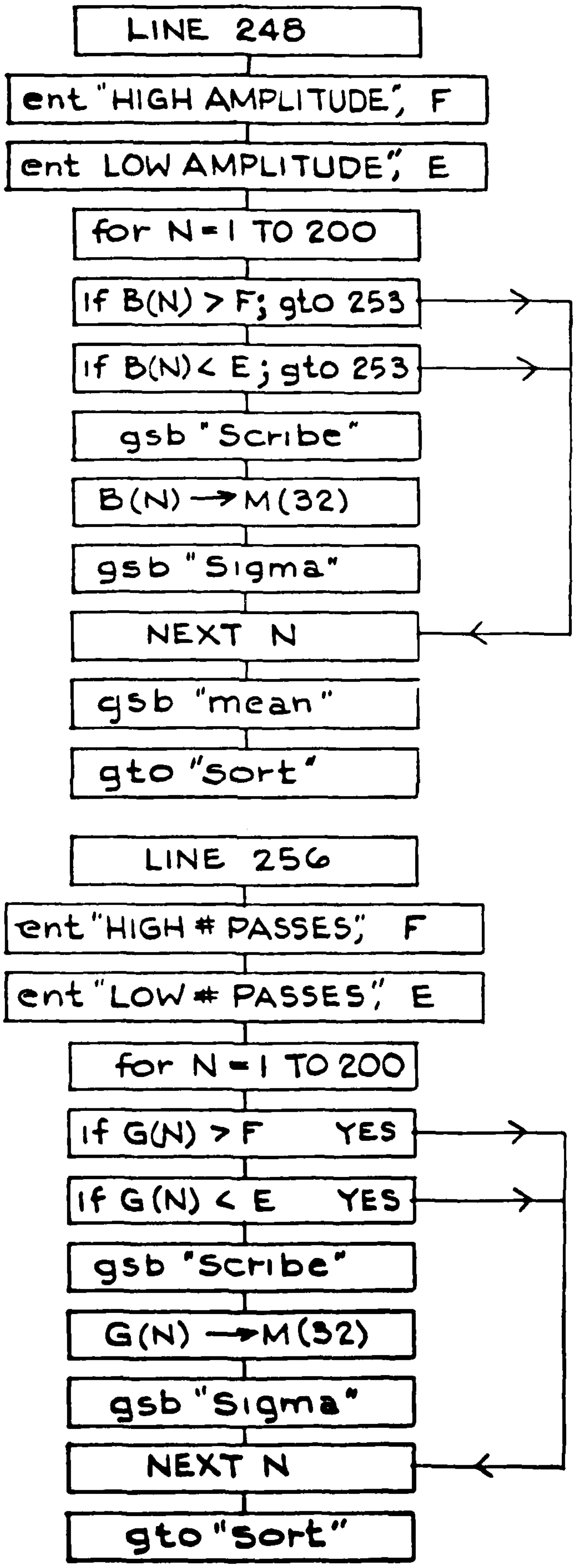
LIST OF COMPLETES

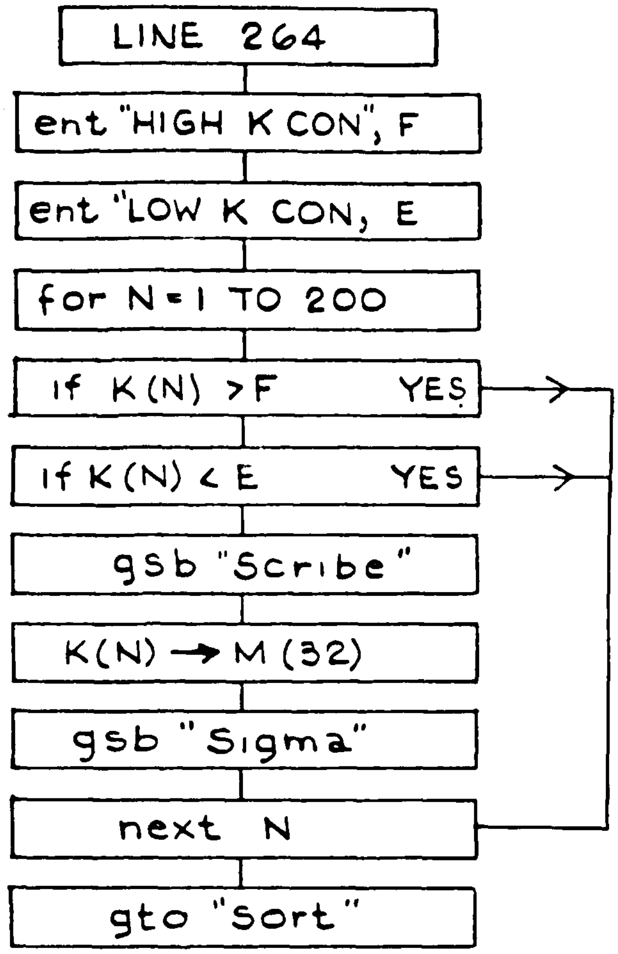


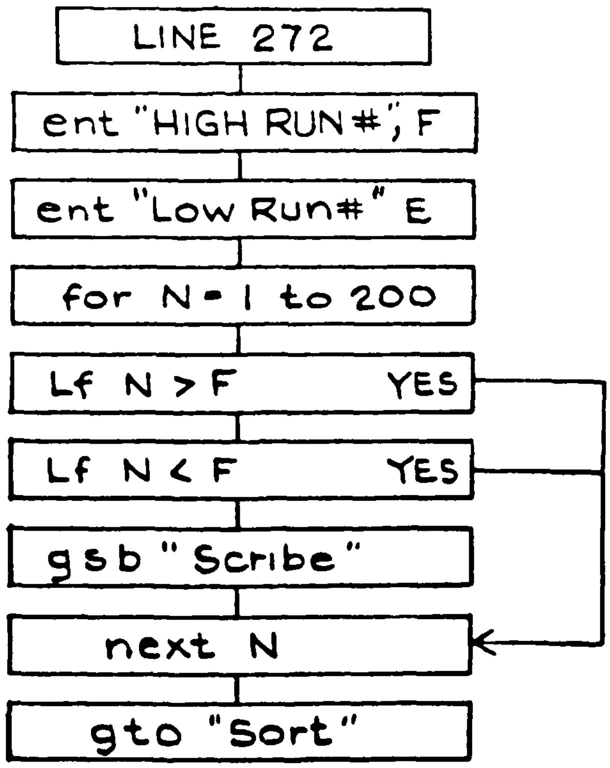

LINE NO.222
ent "TIME HIGH LIMIT" F
ENTER TIME HIGH LIMIT
ent "TIME LOW LIMIT" E
FOR N=1 TO 200
if U(N) > = F; gto 226
NO
if U(N) > = E; gto 226
gsb Scribe
NEXT N
gto sort

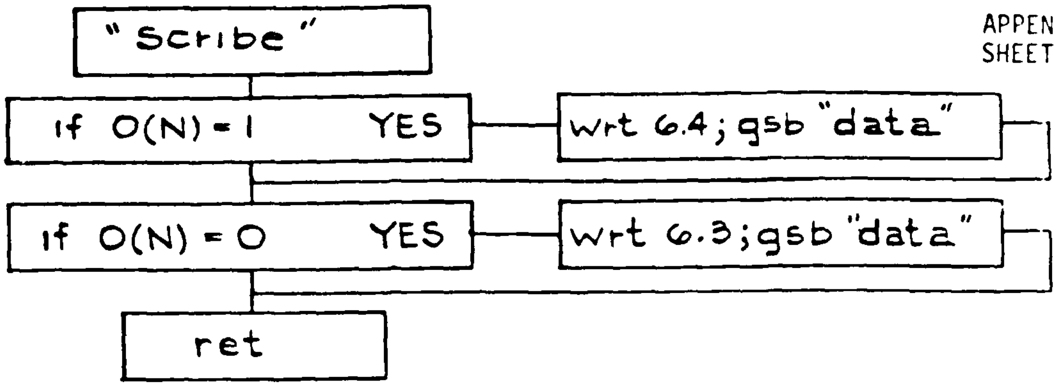

LINE NO.227
ent "HIGH UNIT NO" F
ent "LOW UNIT NO" E
FOR N=1 TO 200
if D(N) < E; gto 231
YES
NO
if D(N) < E; gto 231
NO
YES
gsb "Scribe"
NEXT N
gto "sort"

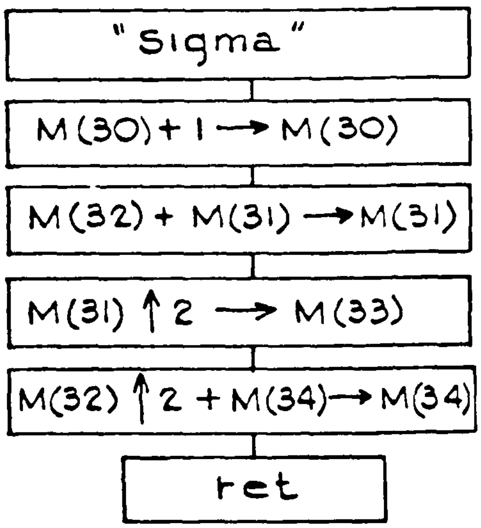

LINE NO. 232
ent "HIGH INITIAL F," F
ent "LOW INITIAL F" E
for N = 1 TO 200
if Z(N) > F; gto 237
YES
NO
if Z(N) < E; gto 237
YES
NO
gsb "Scribe"
Z(N) → M(32)
gsb "sigma"
NEXT N
gsb "mean"
gto "Sort"
LINE NO. 240
ent "HIGH FINAL F" F
ent "LOW FINAL F" E
FOR N = 1 TO 200
if Y(N) > F; gto 245
YES
if Y(N) < E; gto 245
gsb "Scribe"
Y(N) → M(32)
gsb "Sigma"
NEXT N
gsb "mean"
gto "Sort"

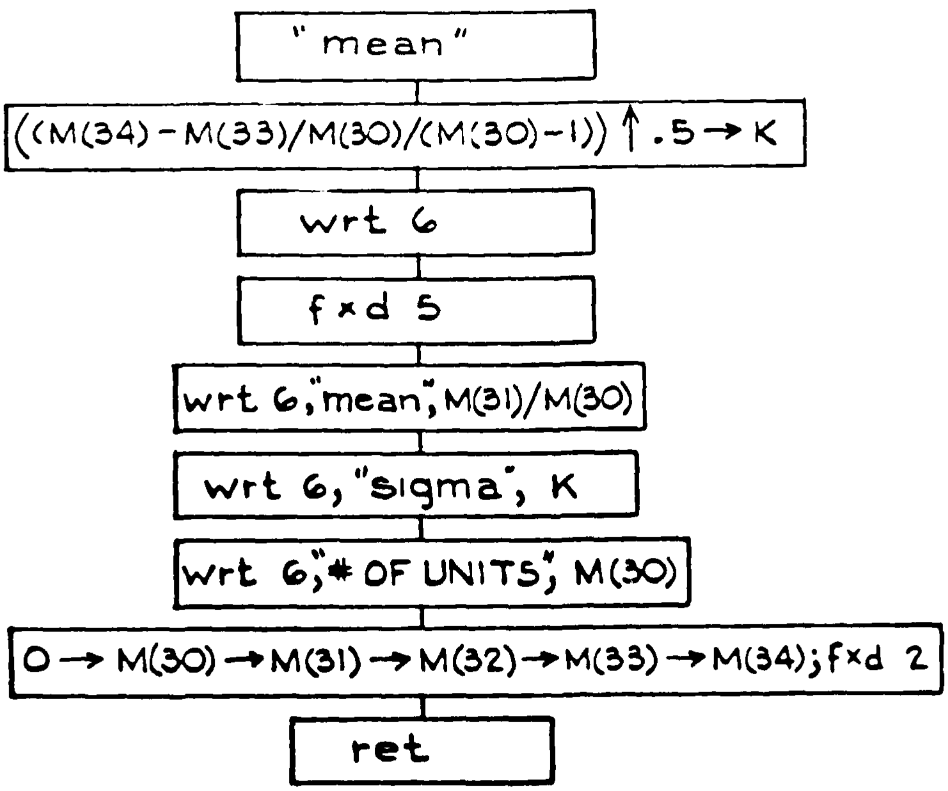

LINE 248
ent "HIGH AMPLITUDE", F
ent LOW AMPLITUDE", E
for N=1 TO 200
if B(N) > F; gto 253
if B(N) < E; gto 253
gsb "Scribe"
B(N) → M(32)
gsb "Sigma"
NEXT N
gsb "mean"
gto "sort"
LINE 256
ent "HIGH # PASSES", F
ent "LOW # PASSES", E
for N=1 TO 200
if G(N) > F YES
if G(N) < E YES
gsb "Scribe"
G(N) → M(32)
gsb "Sigma"
NEXT N
gto "sort"


LINE 264
ent "HIGH K CON", F
ent "LOW K CON, E
for N=1 TO 200
if K(N) >F YES
if K(N) < E YES
gsb "Scribe"
K(N) → M (32)
gsb "Sigma"
next N
gto "Sort"


LINE 272
ent "HIGH RUN#", F
ent "Low Run#" E
for N=1 to 200
Lf N > F YES
Lf N < F YES
gsb "Scribe"
next N
gto "Sort"


"Scribe"
if O(N) = 1 YES
wrt 6.4; gsb "data"
if O(N) = 0 YES
wrt 6.3; gsb "data"
ret


"Sigma"
M(30) + 1 → M(30)
M(32) + M(31) → M(31)
M(31) ↑ 2 → M(33)
M(32) ↑ 2 + M(34) → M(34)
ret

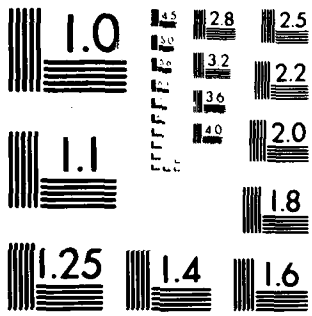

"mean"
((M(34) – M(33)/M(30)/(M(30) – 1)) ↑ .5 → K
wrt 6
fxd 5
wrt 6, "mean", M(31)/M(30)
wrt 6, "sigma", K
wrt 6, "# OF UNITS", M(30)
0 → M(30) → M(31) → M(32) → M(33) → M(34); fxd 2
ret

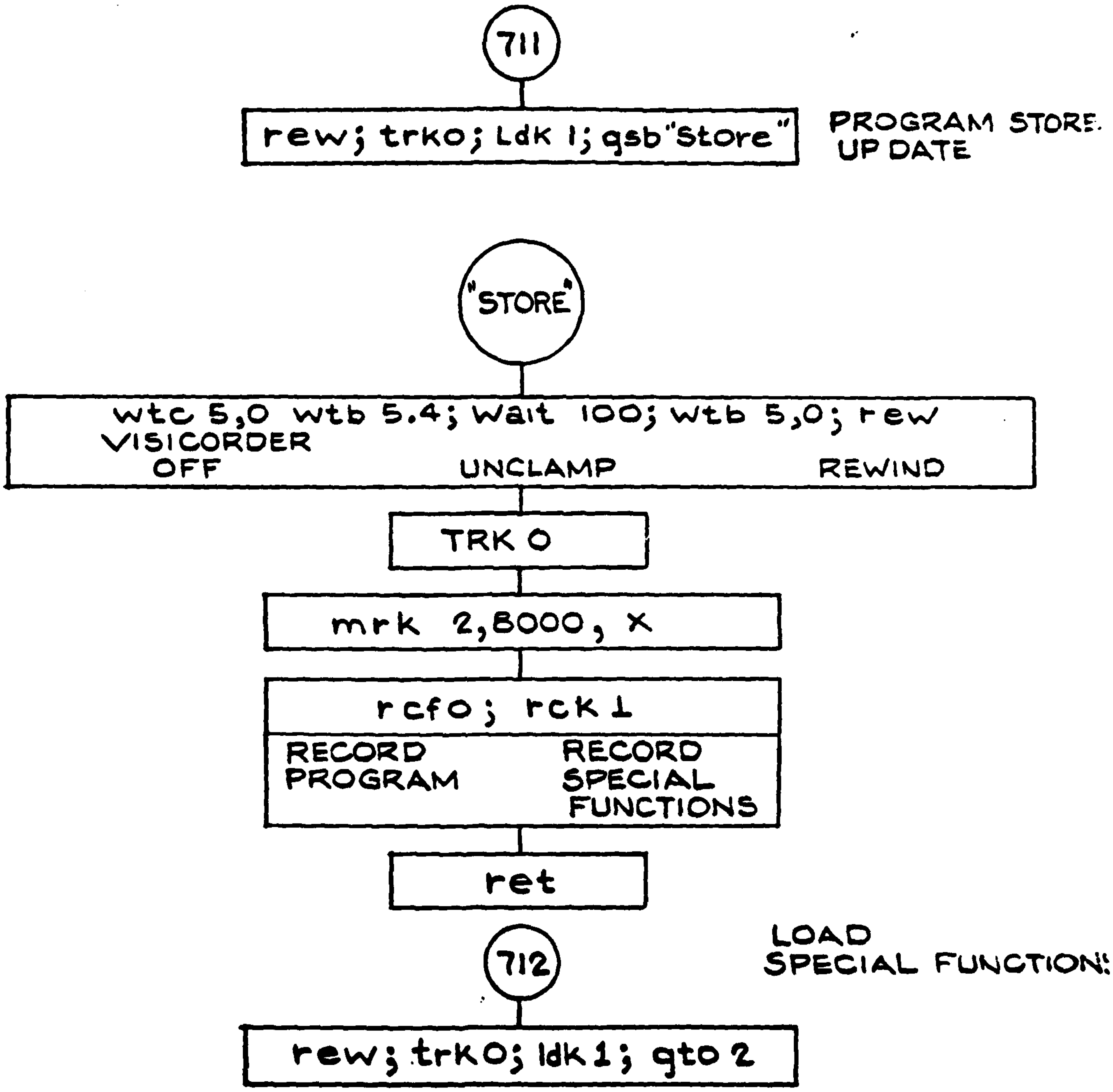
AD-A085 745 BULOVA SYSTEMS AND INSTRUMENTS CORP VALLEY STREAM N Y F/G 19/1
PROTOTYPE AUTOMATED EQUIPMENT TO PERFORM POISING AND BEAT RATE --ETC(U)
SEP 78 C BIRO DAAA21-76-C-0157

UNCLASSIFIED NL

2 of 2

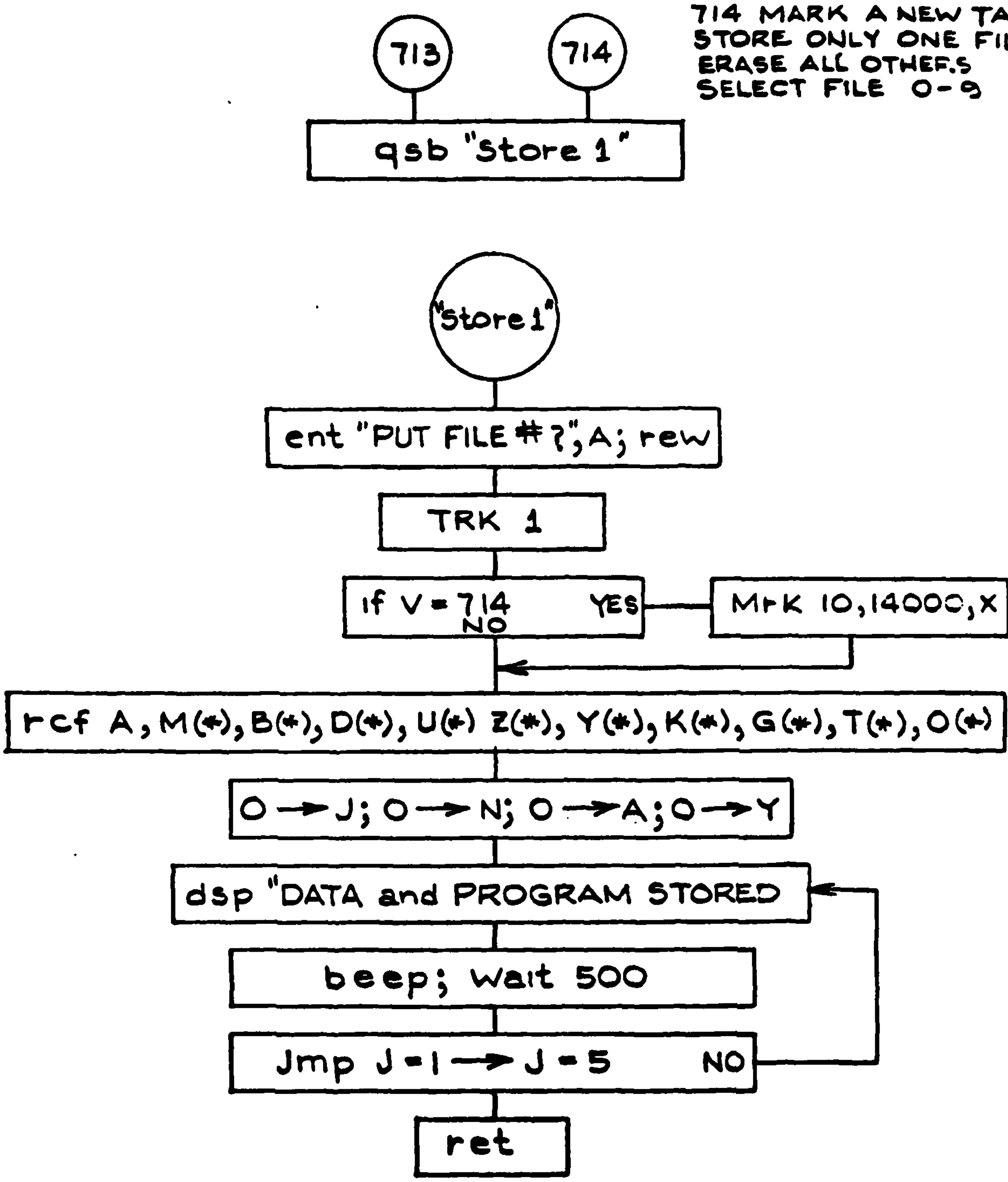
END
DATE FILMED
7 80
DTIC

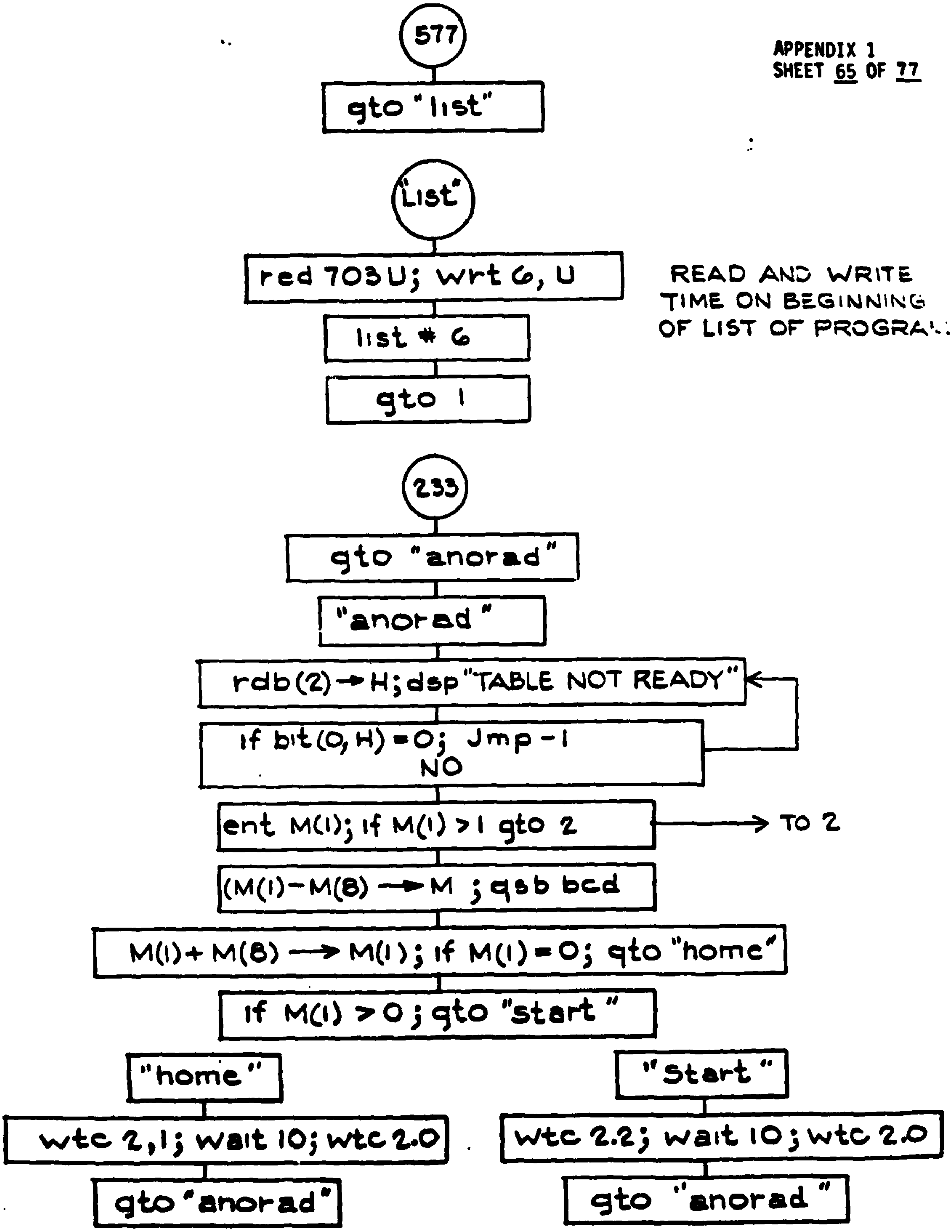

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

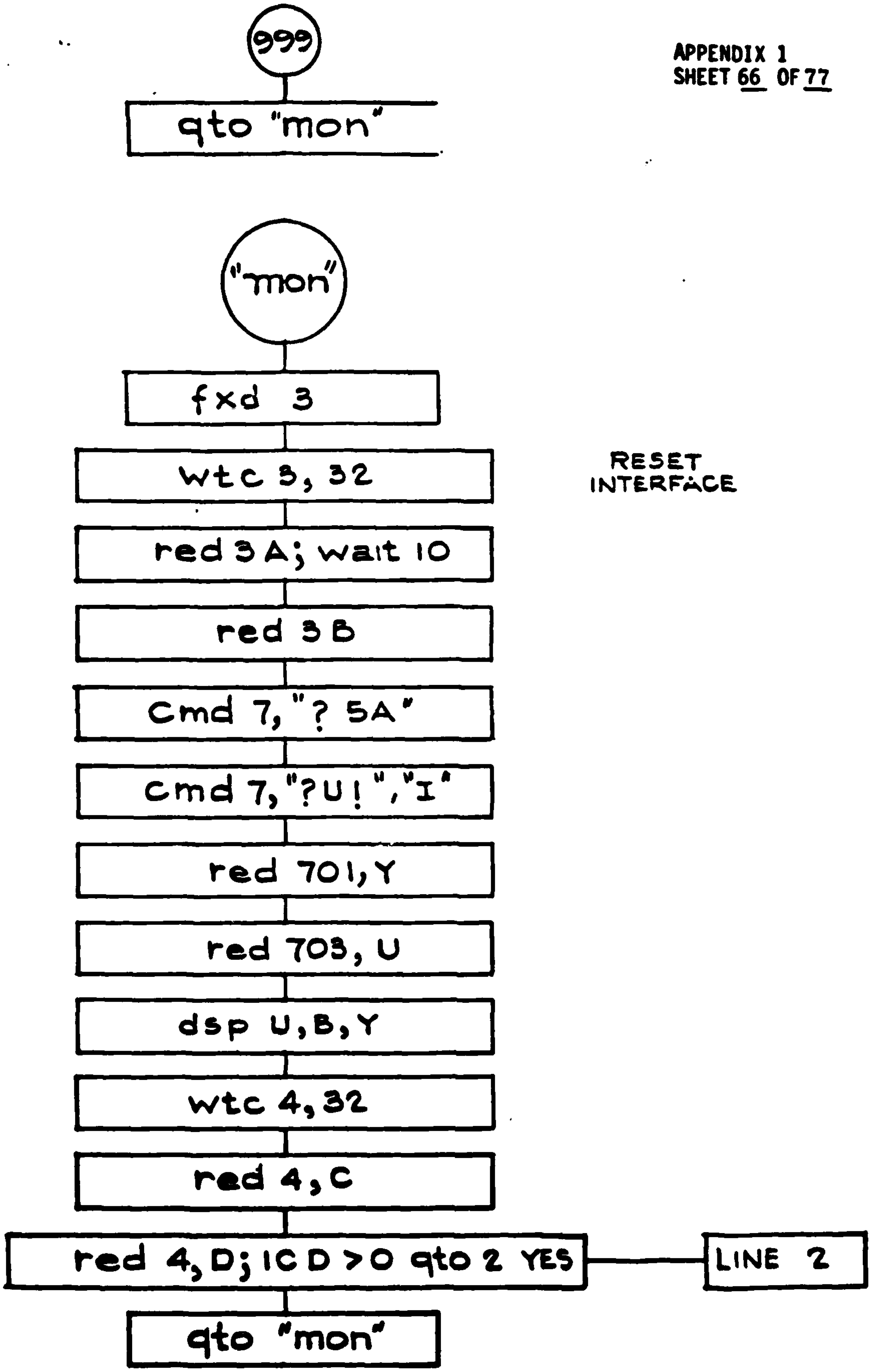

711
rew; trko; Ldk 1; qsb"Store"
PROGRAM STORE UP DATE
"STORE"
wtc 5,0 wtb 5.4; Wait 100; wtb 5,0; rew
VISICORDER OFF
UNCLAMP
REWIND
TRK 0
mrk 2,8000, x
rcfo; rck 1
RECORD PROGRAM
RECORD SPECIAL FUNCTIONS
ret
712
LOAD SPECIAL FUNCTIONS
rew; trk0; ldk 1; gto 2

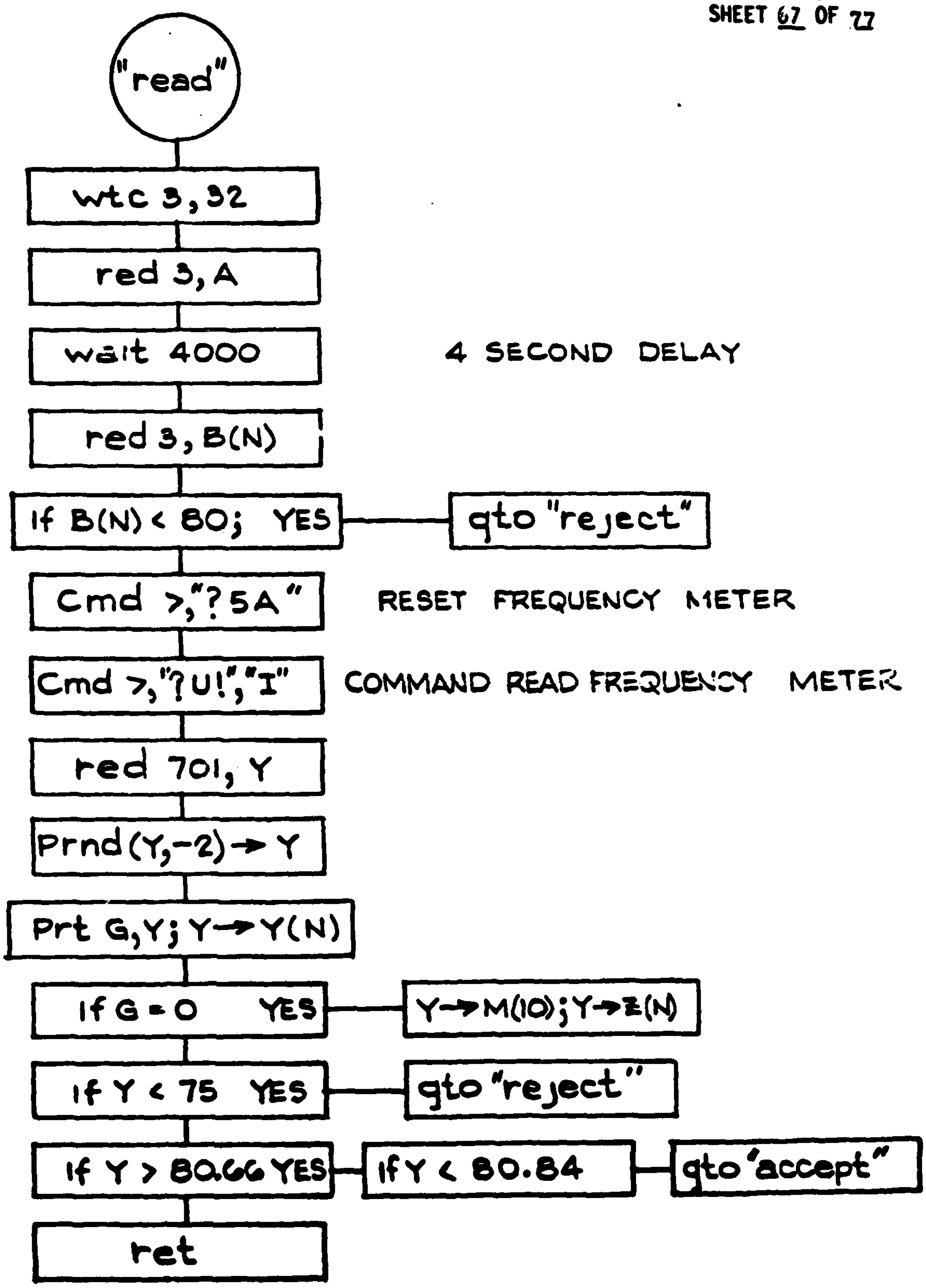
713 STORE DATA ON ANY SELECTED FILE 0-9

714 MARK A NEW TAPE STORE ONLY ONE FILE ERASE ALL OTHERS SELECT FILE 0-9

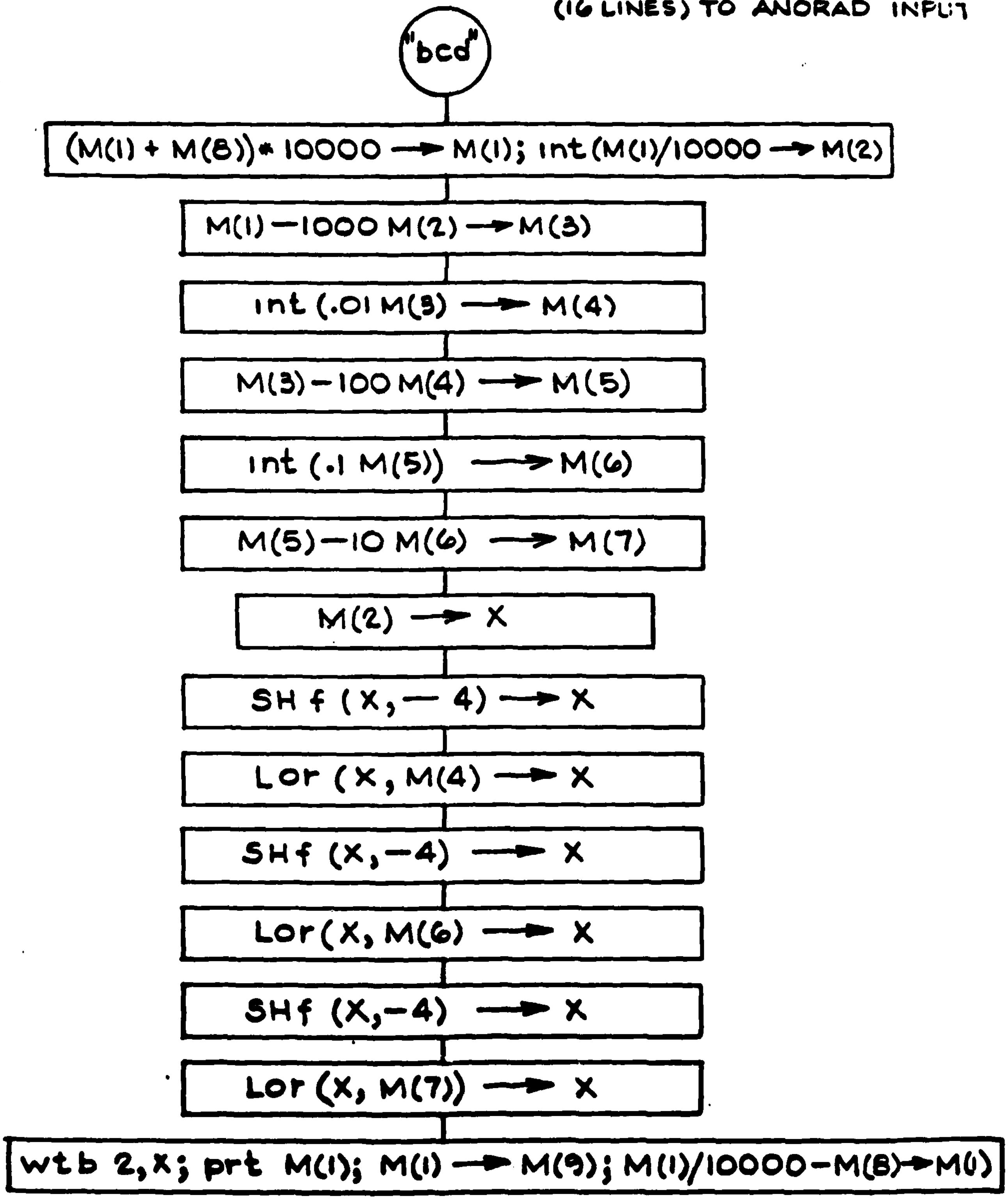



577
gto "list"
"List"
red 703U; wrt 6, U
READ AND WRITE TIME ON BEGINNING OF LIST OF PROGRA...
list # 6
gto 1
233
gto "anorad"
"anorad"
rdb(2) → H; dsp "TABLE NOT READY"
if bit(0, H) = 0; Jmp -1
NO
ent M(1); if M(1) > 1 gto 2
TO 2
(M(1) - M(8) → M ; gsb bcd
M(1) + M(8) → M(1); if M(1) = 0; gto "home"
if M(1) > 0; gto "start"
"home"
wtc 2,1; wait 10; wtc 2.0
gto "anorad"
"Start"
wtc 2.2; wait 10; wtc 2.0
gto "anorad"


999
qto "mon"
"mon"
fxd 3
wtc 3, 32
RESET INTERFACE
red 3 A; wait 10
red 3 B
cmd 7, "? 5A"
cmd 7, "?U! ","I"
red 701, Y
red 703, U
dsp U, B, Y
wtc 4, 32
red 4, C
red 4, D; IC D > 0 gto 2 YES
LINE 2
gto "mon"

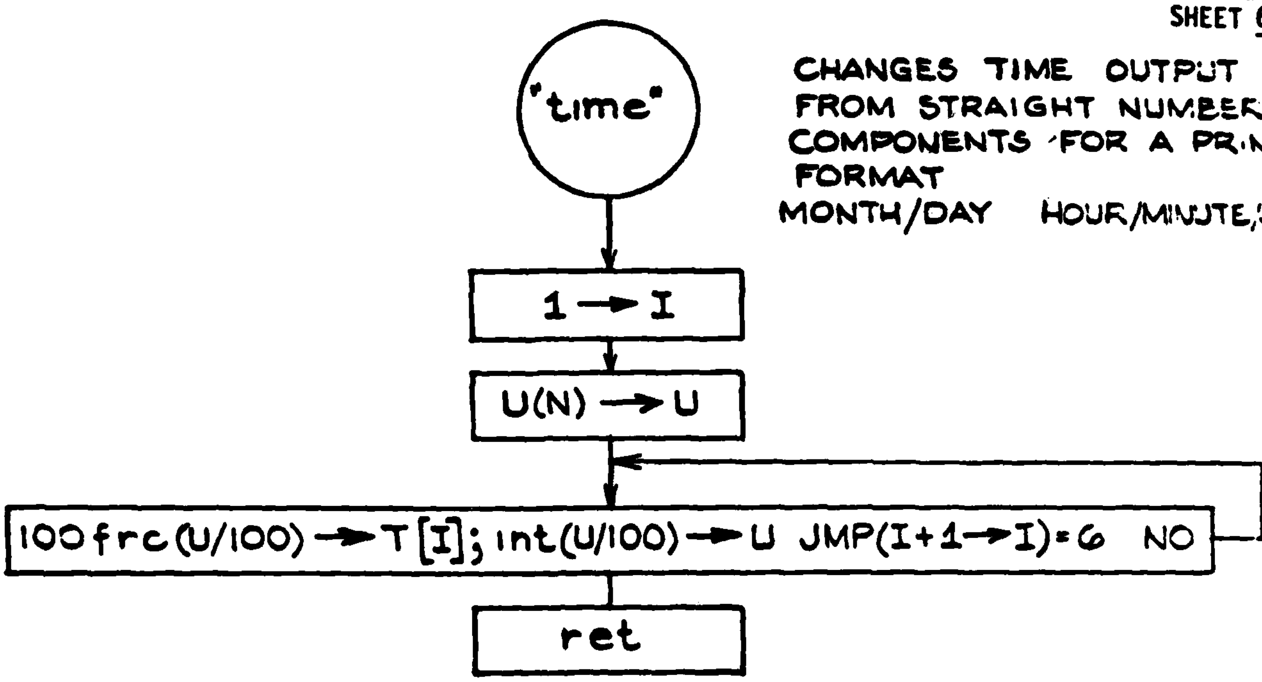

"read"
wtc 3,32
red 3,A
wait 4000
4 SECOND DELAY
red 3,B(N)
If B(N) < 80; YES
gto "reject"
Cmd >,"?5A"
RESET FREQUENCY METER
Cmd >,"?U!","I"
COMMAND READ FREQUENCY METER
red 701,Y
Prnd(Y,-2) → Y
Prt G,Y; Y → Y(N)
If G = 0 YES
Y → M(10); Y → Z(N)
If Y < 75 YES
gto "reject"
If Y > 80.66 YES
If Y < 80.84
gto "accept"
ret

CHANGE THE DISTANCE VALUE FROM .9999 020 bcd LINES (16 LINES) TO ANORAD INPUT

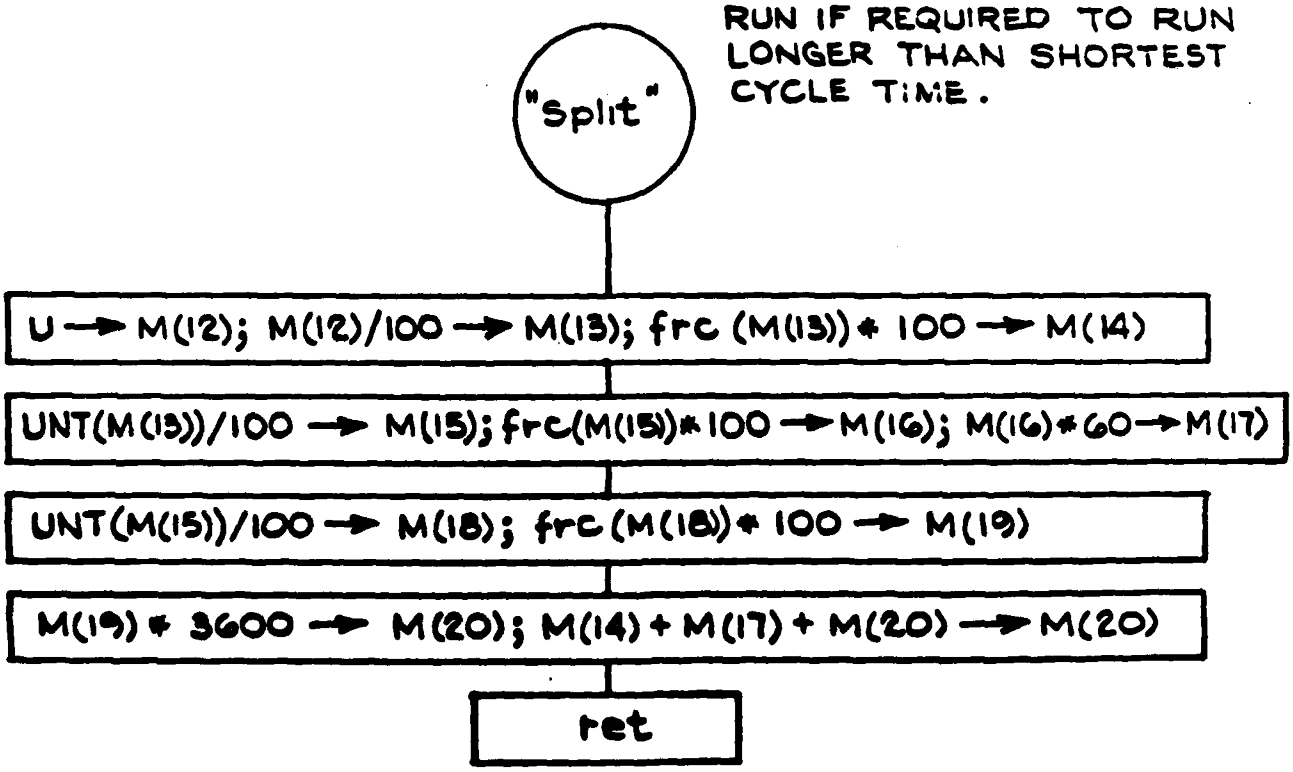


wtb 2,X WRITES a bcd NUMBER INTO ANORAD

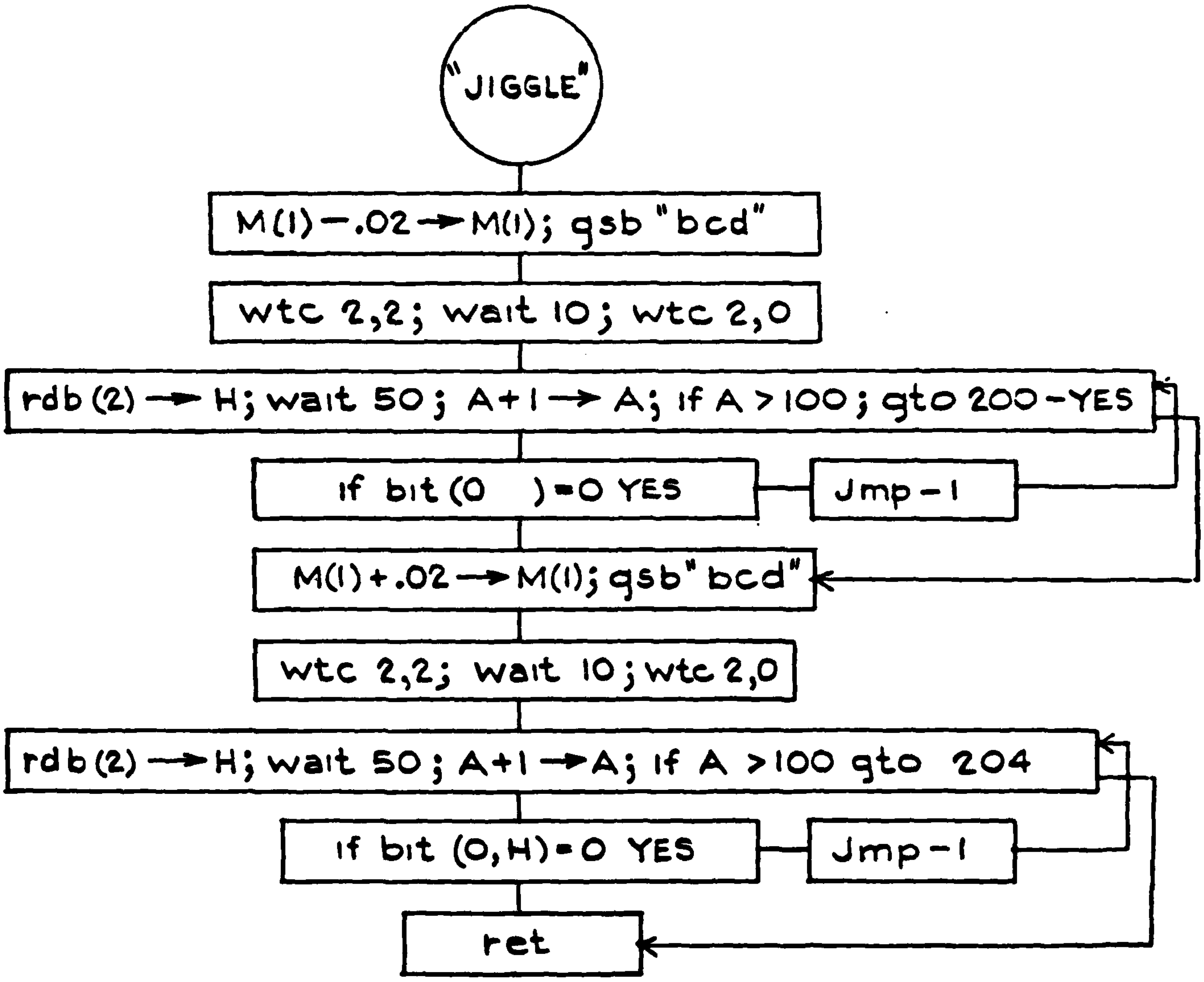
CHANGES TIME OUTPUT FROM STRAIGHT NUMBER TO COMPONENTS FOR A PRINTED FORMAT
MONTH/DAY HOUR/MINUTE/SECOND



CONVERTS TIME OUTPUT TO THE NUMBER OF SECONDS FOR TOTAL ELAPSED TIME OF RUN IF REQUIRED TO RUN LONGER THAN SHORTEST CYCLE TIME.



MAY BE USED TO JIGGLE WELD FREE FROM ANVILS IF THEY STICK



12.0 PROGRAM LISTING

12.1 Automatic Welding Machine

Following is a Program Listing for the Automatic Welding Machine.

```
1: 0→N;200→P;0→V;wtc 2,32;wtb 2,0;wtc 5,32;wtb 5,0;.64→M[9];5→M[21]
2: fxd 2;.03→M[22];0→M[23];ent "0-RUN,1-DATA",V
3: if V=0;gto 19
4: if V=1;gto 19
5: if V=2;gto 18
6: if V=3;gto 19
7: if V=4;gto 19
8: if V=710;rew;trk 0;gsb "store"
9: if V=711;rew;trk 0;ldk 1;gsb "store"
10: if V=712;rew;trk 0;ldk 1;gto 2
11: if V=713;gsb "storel"
12: if V=714;gsb "storel"
13: if V=577;gto "list"
14: if V=995;gto "enter"
15: if V=233;gto "anorad"
16: if V=999;gto "mon"
17: gto 2
18: ent "Starting Run#",N;N-1→N;ent "Final Run# Stored",P;gto 2
19: fmt 1,17x,"Date",5x,"Time",8x,"Unit#",5x,"Initial F",z
20: fmt 2,5x,"Final F",5x,"Amplitude",5x,"#passes",5x,"Kcom",3x,"Run#"
21: fmt 3,3x,"REJECT",2x,z
22: fmt 4,3x,"COMPLETE",z
23: fmt 5,5x,2fz2.0,5x,fz2.0,":",fz2.0,":",fz2.0,5x,fz4.0,8x,f6.3,z
24: fmt 6,7x,f6.3,7x,fz3.0,10x,fz2.0,8x,fz7.5,5x,fz4.0
25: if V=1;gto "print"
26: if V=3;gto "sort"
27: if N=0;gto 30
28: if O[N]=1;wtb 5,8;gto 30
29: if O[N]=0;wtb 5,16
30: if N>=P;gsb "storel"
31: rdb(5)→S
32: if V=4;if bit(0,S)=0;dsp "S0 OPEN,START",N+1;jmp -1
33: wtb 5,0;if bit(1,S)=1;dsp "S4 OPEN,PART MONITOR";jmp -2
34: if bit(2,S)=1;dsp "S1 OPEN,UNCLAMP REAR";jmp -3
35: if bit(3,S)=1;dsp "S2 OPEN,UNCLAMP CENTER";jmp -4
36: if bit(4,S)=0;gto 2;dsp "S3 CLAMPED"
37: if bit(6,S)=1;dsp "HOOD OPEN";jmp -6
38: wtb 5,2;wait 100;wtb 5,0;red 703,U;prt " ";prt U;gsb "split"
39: M[20]→M[11]
40: rdb(5)→S
41: if bit(4,S)=0;gto 43
42: dsp "******[PART NOT CLAMPED]******";wait 500;dsp " ";wait 500;gto 40
43: wtc 2,1;wait 10;wtc 2,0;dsp "Home table";wtc 5,1
44: rdb(2)→H;dsp "TABLE NOT READY"
45: if bit(0,H)=0;jmp -1
46: 0→M[1];gsb "bcd"
47: wtc 2,2;wait 10;wtc 2,0;dsp "initial position"
48: rdb(2)→H;dsp "TABLE NOT READY"
49: if bit(0,H)=0;jmp -1
50: "ready":N+1→N
*27812
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51: wtb 5,1;wait 500;wtb 5,0
52: rdb(5)→S;dsp "weld down"
53: if bit(5,S)=0;jmp -1
54: wtc 3,32;dsp "reset unit counter"
55: red 3,A;wait 10
56: red 3,B[N]
57: dsp "wtb 5,2^10";dsp "launch"
58: red 703,U[N];dsp "read time date"
59: wtc 4,32;dsp "reset 4"
60: red 4,C;dsp "read unit #"
61: red 4,D[N];dsp "sequence 4";prt D[N];if D[N]=0;gto "mon"
62: 0→K[N];0→G
63: gsb "read"
64: if 80.76-Y<0;gto "accept"
65: if 80.76-Y>.5;(80.76-Y)*M[22]→L;gto 70
66: if W=1;if 80.76-Y<=.5;if 80.76-Y>.1;(80.76-Y)*M[22]→L;gto 70
67: if 80.76-Y<=.5;if 80.76-Y>.1;(80.76-Y)*M[22]*.6→L;1→W;gto 70
68: if W=1;if 80.76-Y<=.2;(80.76-Y)*M[22]→L;gto 70
69: if 80.76-Y<=.2;(80.76-Y)*M[22]*.6→L;1→W
70: G+1→G;G→G[N];if G>9;gto "accept"
71: L+M[1]→M[1];gsb "bcd"
72: 0→A;wtc 2,2;wait 10;wtc 2,0
73: rdb(2)→H;dsp "TABLE NOT READY";wait 50;A+1→A;if A>50;gto 75
74: if bit(0,H)=0;jmp -1
75: wtb 5,1;wait 500;wtb 5,0;dsp "weld"
76: rdb(5)→S;dsp "weld down"
77: if bit(5,S)=0;jmp -1
78: gsb "read"
79: if Y<80.68;gto 64
80: if Y>80.86;gto "reject"
81: if B[N]<80;gto "reject"
82: gto "accept"
83: "read":
84: wtc 3,32;dsp "command datel"
85: red 3,A;wait 2000
86: red 3,B[N];if B[N]<80;gto "reject"
87: cmd 7,"?5A"
88: cmd 7,"?U!","I"
89: red 701,Y;prnd(Y,-2)→Y;prt G,Y;Y→Y[N];if G=0;Y→M[10];Y→Z[N]
90: if Y<75;gto "reject"
91: if Y>80.68;if Y<80.86;gto "accept"
92: ret
93: "bcd":(M[1]+M[8])*10000→M[1];int(M[1]/1000)→M[2]
94: M[1]-1000M[2]→M[3]
95: int(.01M[3])→M[4]
96: M[3]-100M[4]→M[5]
97: int(.1M[5])→M[6]
98: M[5]-10M[6]→M[7]
99: M[2]→X
100: shf(X,-4)→X
*13902
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101: ior(X,M[4])→X
102: shf(X,-4)→X
103: ior(X,M[6])→X
104: shf(X,-4)→X
105: ior(X,M[7])→X
106: wtb 2,X;prt M[1];M[1]→M[9];M[1]/10000-M[8]→M[1]
107: ret
108: "time":1→I;U[N]→U
109: 100frc(U/100)→T[I];int(U/100)→U;jmp (I+1→I)=6
110: ret
111: "reject":0→O[N];wrt 6;wtb 5,4;wait 100;wtb 5,0;wtc 2,1;wait 10;wtc 2,0
112: wtc 5,0;red 703,U;prt U;0→W
113: wtb 5,32;wrt 6.1;wrt 6.2;wrt 6.3;gsb "data"
114: rdb(5)→S
115: if bit(6,S)=0;dsp "REJECT";jmp -1
116: wtb 0;gto 19
117: "accept":1→O[N];0→W
118: if Y-M[10]>0;if M[9]/10000-M[8]>0;(M[9]/10000-M[3])/(Y-M[10])→K[N]
119: if Y<80.68;gto "reject"
120: if Y>80.86;gto "reject"
121: if B[N]<80;gto "reject"
122: wrt 6;wtb 5,4;wait 100;wtb 5,0;wtc 2,1;wait 10;wtc 2,0
123: wtc 5,0;red 703,U;prt U;gsb "split"
124: if M[20]-M[11]<M[21];jmp -1
125: wtb 5,32;wrt 6.1;wrt 6.2;wrt 6.4;gsb "data"
126: rdb(5)→S
127: if bit(6,S)=0;dsp "COMPLETE";jmp -1
128: wtb 0;dsp "if K[N]<.01;.027→K[N]";gto 136
129: M[27]+1→M[27];prt M[27];if M[27]=1;K[N]→M[26]
130: if M[27]=2;K[N]→M[28]
131: if M[27]=3;K[N]→M[29];0→M[27]
132: M[26]+M[28]+M[29]→M[23];M[23]/3→M[22];if M[22]>.03;.027→M[22]
133: if M[29]=0;.027→M[22]
134: prt "M[23]",M[23]*10000
135: prt "M[22]",M[22]*10000
136: gto 19
137: "print":ent "GET File #?",A
138: trk 1
139: ldf A,M[*],B[*],D[*],U[*],Z[*],Y[*],K[*],G[*],T[*],O[*]
140: wrt 6;wrt 6.1;wrt 6.2
141: ent "Start Run#",E
142: ent "Finish Run#",F
143: for N=E to F
144: if O[N]=1;wrt 6.4;gsb "data"
145: if O[N]=0;wrt 6.3;gsb "data"
146: next N
147: trk 0;0→A;gto 2
148: "data":gsb "time"
149: wrt 6.5,T[5],"/",T[4],T[3],T[2],T[1],D[N],Z[N]
150: wrt 6.6,Y[N],B[N],G[N],K[N],N
*9306
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151: ret
152: gto 168
153: "store":wtc 5,0;wtb 5,4;wait 100;wtb 5,0;rew
154: trk 0
155: mrk 2,8000,X
156: rcf 0;rck 1
157: ret
158: "store1":ent "PUT File #?",A;rew
159: trk 1
160: if V=714;mrk 10,14000,X
161: rcf A,M[*],B[*],D[*],U[*],Z[*],Y[*],K[*],G[*],T[*],O[*]
162: 0→J;0→N;0→A
163: dsp "DATA and PROGRAM STORED";beep;wait 500;jmp (J+1→J)=5
164: ret
165: "list":red 703,U;wrt 6,U
166: list #6
167: gto 1
168: "mon":
169: fxd 3
170: wtc 3,32
171: red 3,A;wait 10
172: red 3,B
173: cmd 7,"?5A"
174: cmd 7,"?U!","I"
175: red 701,Y
176: red 703,U
177: dsp U,B,Y
178: wtc 4,32
179: red 4,C
180: red 4,D;if D>0;fxd 2;gto 2
181: gto "mon"
182: "anorad":
183: rdb(2)→H;dsp "TABLE NOT READY"
184: if bit(0,H)=0;jmp -1
185: ent M[1];if M[1]>1;gto 2
186: M[1]-M[8]→M[1];gsb "bcd"
187: M[1]+M[8]→M[1];if M[1]=0;gto "home"
188: if M[1]>0;gto "start"
189: "home":
190: wtc 2,1;wait 10;wtc 2,0
191: gto "anorad"
192: "start":
193: wtc 2,2;wait 10;wtc 2,0
194: gto "anorad"
195: "split":
196: U→M[12];M[12]/100→M[13];frc(M[13])*100→M[14]
197: int(M[13])/100→M[15];frc(M[15])*100→M[16];M[16]*60→M[17]
198: int(M[15])/100→M[18];frc(M[18])*100→M[19]
199: M[19]*3600→M[20];M[14]+M[17]+M[20]→M[20]
200: ret
*15909
```

```
201: "jiggle":
202: M[1]-.02→M[1];gsb "bcd"
203: wtc 2,2;wait 10;wtc 2,0
204: rdb(2)→H;dsp "TABLE NOT READY";wait 50;A+1→A;if A>100;gto 205
205: if bit(0,H)=0;jmp -1
206: M[1]+.02→M[1];gsb "bcd"
207: wtc 2,2;wait 10;wtc 2,0
208: rdb(2)→H;wait 50;A+1→A;if A>100;gto 210
209: if bit(0,H)=0;jmp -1
210: ret
211: "sort":wrt 6
212: ent "column",A
213: if A=0;gto 224
214: if A=1;gto 226
215: if A=2;gto 228
216: if A=3;gto 233
217: if A=4;gto 229
218: if A=5;gto 246
219: if A=6;gto 254
220: if A=7;gto 262
221: if A=8;gto 270
222: if A=9;gto 278
223: if A>=10;gto 2
224: for N=1 to 200;if O[N]=0;if U[N]>1;wrt 6.3;gsb "data"
225: next N;gto "sort"
226: for N=1 to 200;if O[N]=1;wrt 6.4;gsb "data"
227: next N;gto "sort"
228: ent "Time High Limit",F;ent "Time Low Limit",E
229: for N=1 to 200;if U[N]>=F;gto 232
230: if U[N]<E;gto 232
231: gsb "scribe"
232: next N;gto "sort"
233: ent "High Unit #",F;ent "Low Unit #",E
234: for N=1 to 200;if D[N]>F;gto 237
235: if D[N]<E;gto 237
236: gsb "scribe"
237: next N;gto "sort"
238: ent "High Initial F",F;ent "Low Initial F",E
239: for N=1 to 200;if Z[N]>F;gto 243
240: if Z[N]<E;gto 243
241: gsb "scribe"
242: Z[N]→M[32];gsb "sigma"
243: next N
244: gsb "mean"
245: gto "sort"
246: ent "High Final F",F;ent "Low Final F",E
247: for N=1 to 200;if Y[N]>F;gto 251
248: if Y[N]<E;gto 251
249: gsb "scribe"
250: Y[N]→M[32];gsb "sigma"
*7869
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251: next N
252: gsb "mean"
253: gto "sort"
254: ent "High Amplitude",F;ent "Low Amplitude",E
255: for N=1 to 200;if B[N]>F;gto 259
256: if B[N]<E;gto 259
257: gsb "scribe"
258: B[N]→M[32];gsb "sigma"
259: next N
260: gsb "mean"
261: gto "sort"
262: ent "High # Passes",F;ent "Low # Passes",E
263: for N=1 to 200;if G[N]>F;gto 267
264: if G[N]<E;gto 267
265: gsb "scribe"
266: G[N]→M[32];gsb "sigma"
267: next N
268: gsb "mean"
269: gto "sort"
270: ent "High Kcom",F;ent "Low Kcom",E
271: for N=1 to 200;if K[N]>F;gto 275
272: if K[N]<E;gto 275
273: gsb "scribe"
274: K[N]→M[32];gsb "sigma"
275: next N
276: gsb "mean"
277: gto "sort"
278: ent "High Run #",F;ent "Low Run #",E
279: for N=1 to 200;if N>F;gto 282
280: if N<E;gto 282
281: gsb "scribe"
282: next N;gto "sort"
283: "scribe":if O[N]=1;wrt 6.4;gsb "data"
284: if O[N]=0;wrt 6.3;gsb "data"
285: ret
286: "enter":ent "Value",M[32]
287: if M[32]=0;gto "alpha"
288: gsb "sigma"
289: gto "enter"
290: "alpha":gsb "mean"
291: gto 2
292: "sigma":M[30]+1→M[30];M[32]+M[31]→M[31]
293: M[31]^2→M[33];M[32]^2+M[34]→M[34]
294: ret
295: "mean":((M[34]-M[33]/M[30])/(M[30]-1))^.5→K
296: wrt 6;fxd 5;wrt 6,"MEAN",M[31]/M[30]
297: wrt 6,"SIGMA",K
298: wrt 6,"#of UNITS",M[30]
299: 0→M[30]→M[31]→M[32]→M[33]→M[34];fxd 2
300: ret
301: end
*6784
```

APPENDIX II

FIELD TEST RESULTS

APPENDIX II

M577 MTSQ Fuze, Automatic Regulation Configuration Field Tests, Yuma Proving Ground.

Lot BL100 Firing Test Results

Timers regulated on Manual Feasibility Test Fixture #661-60001

Balance Wheel Poising = standard production type

Dates of test, 19 and 20 September 1977

Synopsis of 8 Groups

Cal. / Zone	Tube	Temp. ° F	Setting	Function	$\overline{X}$	Sigma
105mm/7	M103	70	3 sec.	14/15	2.929	.076
8 inch/1	M2A1	70	15	15/15	14.991	.041
155mm/8	M185	70	50	14/15	49.988	.091
155mm/8	M185	70	75	14/15	74.962	.128
105mm/7	M103	70	50	14/15	50.008	.077
8 inch/1	M2A1	-35	25	14/15	24.881	.064
105mm/7	M103	145	50	15/15	50.076	.087
175mm/3	-	70	120	14/15	120.323	.166

BULOVA SYSTEMS & INSTRUMENTS CORPORATION

APPENDIX II

Lot BL-200 Firing Test Results

Timers regulated on Automatic Regulation Machine

Balance Wheel poised on Automatic Poising Machine

Date of Test, 18 November 1978

Synopsis of 8 Groups

Cal./Zone	Tube	Temp. ° F	Setting	Function	$\overline{X}$	Sigma
155mm/8	M185	70	50	15/15	50.016	.080
155mm/8	M185	70	75	15/15	74.979	.188
105mm/7	M103	70	50	15/15	50.016	.072
105mm/7	M103	145	50	15/15	50.064	.114
105mm/7	M103	70	3	14/15	3.019	.043
8 inch/1	M2A1	70	15	15/15	14.936	.087
8 inch/1	M2A1	-35	25	15/15	24.928	.086
175mm/3	-	70	120	10/15	120.284	.209

APPENDIX III

ACCEPTANCE TEST RESULTS

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Ecor	Run#
COMPLETE	06/26	08:16:19	0001	79.540	80.760 −.09 80.67	122 125	02	0.03787	0001
COMPLETE	06/26	08:16:49	0001	79.910	80.790 −.08 80.71	120 123	02	0.03511	0002
COMPLETE	06/26	08:17:13	0001	79.800	80.790 −.07 80.72	116 121	02	0.03486	0003
COMPLETE	06/26	08:17:31	0001	80.350	80.830 −.06 80.77	124 123	02	0.03213	0004
REJECT	06/26	08:17:50	0001	0.000	0.000	014	00	0.00000	0005
COMPLETE	06/26	08:18:06	0001	79.520	80.880 −.05 80.83	124 127	03	0.03600	0006
COMPLETE	06/26	08:18:31	0001	79.470	80.850 −.06 80.79	103 101	03	0.03670	0007
COMPLETE	06/26	08:18:55	0001	79.600	80.800 −.04 80.76	124 124	02	0.03655	0008
COMPLETE	06/26	08:19:13	0001	79.980	80.930 −.12 80.81	118 120	02	0.03133	0009
REJECT	06/26	08:19:31	0001	79.480	80.990	119	02	0.00000	0010
REJECT	06/26	08:19:50	0001	80.260	80.990	128	02	0.00000	0011
COMPLETE	06/26	08:20:09	0001	80.520	80.810 −.05 80.76	120 122	01	0.01986	0012
REJECT	06/26	08:20:25	0001	0.000	0.000	073	00	0.00000	0013
COMPLETE	06/26	08:20:35	0001	80.340	80.810 −.05 80.76	116 119	02	0.03511	0014
COMPLETE	06/26	08:20:54	0001	79.580	80.810	130	02	0.03460	0015
COMPLETE	06/26	08:21:16	0001	79.980	80.910	120	03	0.03497	0016
COMPLETE	06/26	08:21:51	0001	80.270	80.850	114	02	0.03569	0017
COMPLETE	06/26	08:22:19	0001	79.960	80.810	125	02	0.03506	0018
COMPLETE	06/26	08:22:45	0001	79.890	80.830	111	02	0.03760	0019
REJECT	06/26	08:23:11	0001	79.680	69.390	085	03	0.00000	0020
COMPLETE	06/26	08:23:45	0001	80.150	80.760	120	03	0.05410	0021
COMPLETE	06/26	08:24:15	0001	79.570	80.760	121	01	0.03202	0022
COMPLETE	06/26	08:24:34	0001	80.010	80.860	124	02	0.03416	0023
REJECT	06/26	08:25:00	0001	82.330	82.330	131	00	0.00000	0024
COMPLETE	06/26	08:25:17	0001	79.240	80.860	121	02	0.04037	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Econ	Run#
COMPLETE	06/26	08:57:51	0001	79.460	80.030 80.75	122 122	02	0.03600	0001
COMPLETE	06/26	09:00:52	0001	79.970	80.020 80.78	122 122	02	0.03346	0002
COMPLETE	06/26	09:01:20	0001	79.780	80.010 80.74	122 120	02	0.03419	0003
COMPLETE	06/26	09:02:20	0001	80.390	80.850 80.79	122 124	02	0.02870	0004
COMPLETE	06/26	09:02:41	0001	80.260	80.790 80.72	104 107	01	0.03283	0005
COMPLETE	06/26	09:03:18	0001	79.270	80.820 80.72	122 119	03	0.03557	0006
COMPLETE	06/26	09:04:02	0001	80.540	80.920 80.78	122 125	02	0.02211	0007
COMPLETE	06/26	09:04:27	0001	79.760	80.810 80.78	121 119	02	0.03754	0008
COMPLETE	06/26	09:04:51	0001	79.600	80.770 80.69	127 128	02	0.03795	0009
COMPLETE	06/26	09:05:16	0001	79.370	80.800 80.74	122 126	02	0.03462	0010
COMPLETE	06/26	09:05:41	0001	80.020	80.850	116	02	0.03419	0011
COMPLETE	06/26	09:06:15	0001	79.310	80.910	122	03	0.03578	0012
COMPLETE	06/26	09:06:40	0001	79.050	80.880	117	02	0.04066	0013
COMPLETE	06/26	09:07:00	0001	79.970	80.880	122	01	0.02860	0014
COMPLETE	06/26	09:07:14	0001	80.710	80.830	126	01	0.01950	0015
COMPLETE	06/26	09:07:31	0001	80.440	80.920	126	03	0.10125	0016
COMPLETE	06/26	09:07:50	0001	80.040	80.800	125	03	0.04057	0017
REJECT	06/26	09:08:23	0001	79.340	81.160	125	03	0.00000	0018
COMPLETE	06/26	09:08:40	0001	78.600	80.790	120	02	0.03446	0019
COMPLETE	06/26	09:09:07	0001	80.400	80.780	125	04	0.00874	0020
COMPLETE	06/26	09:09:40	0001	79.070	80.930	124	02	0.03102	0021
COMPLETE	06/26	09:09:59	0001	80.250	80.800	126	02	0.03324	0022
COMPLETE	06/26	09:10:19	0001	79.470	80.050	124	02	0.03370	0023
REJECT	06/26	09:10:39	0001	79.700	80.960 80.70	126 130	03	0.00000	0024
COMPLETE	06/26	09:11:02	0001	79.730	80.840	119	02	0.03162	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Econ	Run#
COMPLETE	06/26	12:32:08	0004	78.850	80.850	095	02	0.04035	0001
COMPLETE	06/26	12:32:32	0004	79.650	80.780	123	02	0.03414	0002
COMPLETE	06/26	12:32:51	0004	80.370	80.860	116	01	0.01727	0003
COMPLETE	06/26	12:33:06	0004	80.270	80.810	118	02	0.03733	0004
COMPLETE	06/26	12:33:24	0004	79.970	80.920	119	02	0.02994	0005
COMPLETE	06/26	12:33:44	0004	79.480	80.800	124	02	0.03336	0006
COMPLETE	06/26	12:34:06	0004	79.860	80.860	122	02	0.03318	0007
COMPLETE	06/26	12:34:24	0004	79.890	80.820	116	01	0.03065	0008
COMPLETE	06/26	12:34:37	0004	79.360	80.790	120	02	0.04448	0009
COMPLETE	06/26	12:34:56	0004	80.380	80.780	120	01	0.02070	0010
COMPLETE	06/26	12:35:09	0004	80.150	80.770	123	02	0.04065	0011
REJECT	06/26	12:35:29	0004	79.330	81.010	117	03	0.00000	0012
COMPLETE	06/26	12:35:51	0004	78.890	80.760	119	02	0.03225	0013
COMPLETE	06/26	12:36:09	0004	80.080	80.790	113	02	0.03820	0014
REJECT	06/26	12:36:29	0004	79.720	80.980	122	02	0.00000	0015
REJECT	06/26	12:36:47	0004	80.530	84.580	082	02	0.00000	0016
COMPLETE	06/26	12:37:06	0004	79.630	80.800	124	04	0.04103	0017
COMPLETE	06/26	12:37:36	0004	79.970	80.940	124	02	0.03080	0018
COMPLETE	06/26	12:37:55	0004	79.510	80.840	119	01	0.03080	0019
COMPLETE	06/26	12:38:11	0004	79.830	80.860	119	03	0.03580	0020
REJECT	06/26	12:38:37	0004	80.090	80.970	109	01	0.00000	0021
COMPLETE	06/26	12:38:51	0004	80.020	80.890	122	02	0.03283	0022
COMPLETE	06/26	12:39:09	0004	80.400	80.810	123	02	0.02810	0023
COMPLETE	06/26	12:39:28	0004	79.390	80.870	115	02	0.03260	0024
COMPLETE	06/26	12:39:48	0004	80.600	80.860	113	03	0.23767	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Kcor	Run#
REJECT	06/26	12:42:39	0005	79.930	81.000	123	03	0.00000	0001
REJECT	06/26	12:43:04	0005	79.930	80.950	112	01	0.00000	0002
REJECT	06/26	12:43:18	0005	82.130	82.130	126	01	0.00000	0003
REJECT	06/26	12:43:44	0005	80.318	80.950	115	01	0.00000	0004
COMPLETE	06/26	12:43:58	0005	79.510	80.760	127	02	0.03422	0005
COMPLETE	06/26	12:44:17	0005	79.910	80.780	120	01	0.03207	0006
REJECT	06/26	12:44:30	0005	79.630	80.980	119	02	0.00000	0007
COMPLETE	06/26	12:44:51	0005	80.460	80.830	120	02	0.03470	0008
COMPLETE	06/26	12:45:11	0005	79.410	80.900	116	02	0.03097	0009
REJECT	06/26	12:45:30	0005	80.010	80.010	077	01	0.00000	0010
REJECT	06/26	12:45:42	0005	79.500	81.090	121	01	0.00000	0011
REJECT	06/26	12:45:56	0005	79.630	81.320	125	01	0.00000	0012
COMPLETE	06/26	12:46:11	0005	79.390	80.930	112	01	0.02825	0013
COMPLETE	06/26	12:46:28	0005	80.900	80.900	127	02	0.00000	0014
COMPLETE	06/26	12:46:42	0005	79.840	80.860	127	01	0.02941	0015
COMPLETE	06/26	12:46:56	0005	80.230	80.830	120	02	0.03380	0016
COMPLETE	06/26	12:47:17	0005	79.990	80.820	118	01	0.03072	0017
REJECT	06/26	12:47:32	0005	79.540	80.980	124	02	0.00000	0018
REJECT	06/26	12:47:51	0005	80.170	81.060	123	01	0.00000	0019
REJECT	06/26	12:48:06	0005	79.490	81.040	124	01	0.00000	0020
REJECT	06/26	12:48:21	0005	79.830	80.970	123	02	0.00000	0021
COMPLETE	06/26	12:48:40	0005	80.680	80.790	127	02	0.03618	0022
COMPLETE	06/26	12:48:59	0005	79.920	80.920	109	02	0.03264	0023
REJECT	06/26	12:49:16	0005	80.440	80.960	117	02	0.00000	0024
REJECT	06/26	12:49:35	0005	79.350	81.120	124	02	0.00000	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Kcor	Run#
COMPLETE	06/26	13:44:48	0006	78.960	80.910	111	01	0.02892	0001
COMPLETE	06/26	13:45:19	0006	79.380	80.800	117	02	0.03300	0002
COMPLETE	06/26	13:45:42	0006	79.530	80.790	119	02	0.03319	0003
COMPLETE	06/26	13:46:00	0006	79.090	80.840	124	02	0.03329	0004
COMPLETE	06/26	13:46:19	0006	79.920	80.800	102	03	0.04268	0005
REJECT	06/26	13:46:44	0006	80.230	80.980	121	03	0.00000	0006
COMPLETE	06/26	13:47:07	0006	79.810	80.790	116	03	0.04335	0007
COMPLETE	06/26	13:47:30	0006	79.690	80.810	113	01	0.03080	0008
COMPLETE	06/26	13:47:45	0006	80.030	80.870	105	01	0.02893	0009
COMPLETE	06/26	13:47:59	0006	80.160	80.930	116	02	0.03771	0010
COMPLETE	06/26	13:48:17	0006	79.930	80.850	110	01	0.02967	0011
REJECT	06/26	13:48:35	0006	80.090	81.010	122	02	0.00000	0012
COMPLETE	06/26	13:48:53	0006	80.090	80.940	105	02	0.02944	0013
COMPLETE	06/26	13:49:11	0006	79.330	80.760	116	02	0.03583	0014
REJECT	06/26	13:49:29	0006	79.840	81.000	110	02	0.00000	0015
COMPLETE	06/26	13:49:49	0006	79.900	80.760	107	02	0.03907	0016
REJECT	06/26	13:50:07	0006	82.290	82.290	106	00	0.00000	0017
COMPLETE	06/26	13:50:18	0006	79.340	80.830	112	01	0.03020	0018
COMPLETE	06/26	13:50:33	0006	79.770	80.910	115	02	0.03100	0019
COMPLETE	06/26	13:50:52	0006	80.600	80.770	111	01	0.02541	0020
COMPLETE	06/26	13:51:05	0006	78.860	80.790	117	01	0.03078	0021
COMPLETE	06/26	13:51:18	0006	79.560	80.780	109	02	0.03664	0022
COMPLETE	06/26	13:51:36	0006	80.570	80.830	121	01	0.01869	0023
COMPLETE	06/26	13:51:49	0006	79.720	80.900	118	04	0.04195	0024
REJECT	06/26	13:52:16	0006	0.000	0.000	063	00	0.00000	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Kcor	Run#
COMPLETE	06/26	13:53:48	0007	80.270	80.850	108	01	0.02948	0001
COMPLETE	06/26	13:54:03	0007	79.690	80.860	110	02	0.03164	0002
COMPLETE	06/26	13:54:22	0007	80.240	80.920	106	02	0.02991	0003
COMPLETE	06/26	13:54:40	0007	79.430	80.760	112	01	0.03180	0004
COMPLETE	06/26	13:54:54	0007	78.900	80.790	111	02	0.03346	0005
COMPLETE	06/26	13:55:12	0007	79.510	80.870	111	02	0.03146	0006
COMPLETE	06/26	13:55:30	0007	80.410	80.770	112	01	0.02150	0007
COMPLETE	06/26	13:55:44	0007	80.180	80.780	106	01	0.03300	0008
COMPLETE	06/26	13:55:57	0007	80.000	80.840	120	01	0.03000	0009
COMPLETE	06/26	13:56:11	0007	79.970	80.780	124	01	0.03222	0010
REJECT	06/26	13:56:24	0007	79.930	80.850	028	01	0.00000	0011
COMPLETE	06/26	13:56:31	0007	80.070	80.880	113	02	0.03074	0012
COMPLETE	06/26	13:56:49	0007	80.000	80.760	127	02	0.03624	0013
COMPLETE	06/26	13:57:07	0007	79.810	80.940	119	02	0.02894	0014
COMPLETE	06/26	13:57:25	0007	79.660	80.820	123	03	0.03916	0015
COMPLETE	06/26	13:57:48	0007	79.320	80.760	123	01	0.03167	0016
COMPLETE	06/26	13:58:01	0007	79.800	80.830	113	03	0.04282	0017
REJECT	06/26	13:58:23	0007	79.160	81.090	122	02	0.00000	0018
REJECT	06/26	13:58:40	0007	79.580	80.970	120	02	0.00000	0019
COMPLETE	06/26	13:58:58	0007	80.020	80.870	121	02	0.03169	0020
COMPLETE	06/26	13:59:16	0007	79.550	80.790	119	04	0.04423	0021
COMPLETE	06/26	13:59:47	0007	79.220	80.900	122	01	0.02893	0022
COMPLETE	06/26	14:00:01	0007	80.260	80.800	113	02	0.03956	0023
COMPLETE	06/26	14:00:20	0007	79.510	80.810	123	02	0.03200	0024
COMPLETE	06/26	14:00:42	0007	79.220	80.870	117	01	0.02945	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Kcon	Run#
COMPLETE	06/27	09:51:19	0009	79.680	80.910	128	01	0.02829	0001
COMPLETE	06/27	09:51:32	0009	78.600	80.850	116	02	0.03707	0002
COMPLETE	06/27	09:51:50	0009	79.400	80.810	119	03	0.03485	0003
REJECT	06/27	09:52:13	0009	80.150	81.050	124	03	0.00000	0004
REJECT	06/27	09:52:49	0009	0.000	0.000	025	00	0.00000	0005
COMPLETE	06/27	09:53:04	0009	79.800	80.780	128	03	0.03845	0006
REJECT	06/27	09:53:30	0009	80.180	80.980	131	02	0.00000	0007
COMPLETE	06/27	09:53:47	0009	80.440	80.810	126	02	0.03811	0008
COMPLETE	06/27	09:54:06	0009	79.490	80.760	125	02	0.03487	0009
COMPLETE	06/27	09:54:24	0009	79.510	80.850	122	03	0.03703	0010
COMPLETE	06/27	09:54:49	0009	80.020	80.830	125	01	0.03037	0011
COMPLETE	06/27	09:55:05	0009	79.960	80.880	123	02	0.03261	0012
COMPLETE	06/27	09:55:22	0009	79.920	80.860	126	01	0.02936	0013
COMPLETE	06/27	09:55:37	0009	79.880	81.910	125	02	0.03146	0014
REJECT	06/27	09:55:55	0009	81.120	81.120	122	00	0.00000	0015
COMPLETE	06/27	09:56:05	0009	80.000	80.900	120	02	0.03300	0016
COMPLETE	06/27	09:56:24	0009	80.290	80.930	128	01	0.02578	0017
COMPLETE	06/27	09:56:39	0009	79.870	80.850	125	02	0.03392	0018
COMPLETE	06/27	09:57:05	0009	79.580	80.880	120	02	0.03174	0019
COMPLETE	06/27	09:57:27	0009	80.590	80.790	121	01	0.02250	0020
COMPLETE	06/27	09:57:41	0009	79.920	80.860	125	01	0.02936	0021
COMPLETE	06/27	09:57:54	0009	80.030	80.790	124	01	0.03197	0022
COMPLETE	06/27	09:58:11	0009	79.200	80.880	127	02	0.03083	0023
COMPLETE	06/27	09:59:02	0009	80.750	80.790	126	09	0.73000	0001
COMPLETE	06/27	09:59:55	0009	79.810	80.790	127	01	0.03183	0002

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Kcom	Run#
REJECT	06/27	10:05:30	0010	78.260	80.990	120	02	0.00000	0001
REJECT	06/27	10:09:02	0010	0.000	0.000	015	00	0.00000	0002
COMPLETE	06/27	10:10:06	0010	79.370	80.810	115	02	0.03266	0003
REJECT	06/27	10:10:25	0010	0.000	0.000	054	00	0.00000	0004
COMPLETE	06/27	10:10:50	0010	79.900	80.890	119	02	0.03249	0005
COMPLETE	06/27	10:11:11	0010	78.830	80.940	127	03	0.04257	0006
REJECT	06/27	10:11:37	0010	79.560	80.970	124	02	0.00000	0007
COMPLETE	06/27	10:11:59	0010	79.000	80.900	125	02	0.03946	0008
COMPLETE	06/27	10:12:17	0010	79.250	80.960	126	01	0.02963	0009
REJECT	06/27	10:12:36	0010	79.150	80.980	119	02	0.00000	0010
COMPLETE	06/27	10:12:54	0010	78.220	80.770	119	02	0.03351	0011
COMPLETE	06/27	10:13:13	0010	78.760	80.870	123	02	0.03316	0012
COMPLETE	06/27	10:13:34	0010	78.360	80.880	119	03	0.03421	0013
COMPLETE	06/27	10:13:57	0010	79.330	80.790	120	02	0.03547	0014
REJECT	06/27	10:14:15	0010	80.190	80.960	126	01	0.00000	0015
COMPLETE	06/27	10:14:30	0010	78.480	80.770	112	02	0.03359	0016
COMPLETE	06/27	10:14:49	0010	79.810	80.940	119	02	0.03350	0017
COMPLETE	06/27	10:15:12	0010	78.360	80.840	118	03	0.03428	0018
COMPLETE	06/27	10:15:34	0010	78.723	80.910	120	02	0.03740	0019
COMPLETE	06/27	10:15:53	0010	78.400	80.900	123	02	0.04013	0020
COMPLETE	06/27	10:16:11	0010	77.880	80.760	117	02	0.03760	0021
COMPLETE	06/27	10:16:29	0010	79.530	80.770	121	02	0.03222	0022
COMPLETE	06/27	10:16:47	0010	79.810	80.930	122	02	0.03451	0023
COMPLETE	06/27	10:17:09	0010	80.100	80.830	117	02	0.03337	0024
COMPLETE	06/27	10:17:30	0010	79.460	80.940	113	03	0.03391	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Kcon	Run#
COMPLETE	06/27	10:28:00	0011	79.160	80.060	114	02	0.03293	0001
REJECT	06/27	10:28:19	0011	79.810	80.980	123	02	0.00000	0002
COMPLETE	06/27	10:28:38	0011	79.810	80.900	122	02	0.03248	0003
COMPLETE	06/27	10:28:57	0011	79.540	80.830	113	02	0.03595	0004
REJECT	06/27	10:29:14	0011	79.820	81.060	125	01	0.00000	0005
COMPLETE	06/27	10:29:29	0011	80.150	80.860	117	02	0.03346	0006
COMPLETE	06/27	10:29:47	0011	80.380	80.820	124	02	0.03859	0007
REJECT	06/27	10:30:09	0011	79.840	80.950	121	02	0.00000	0008
REJECT	06/27	10:30:27	0011	79.580	81.040	111	03	0.00000	0009
COMPLETE	06/27	10:30:50	0011	79.780	80.810	123	02	0.03402	0010
COMPLETE	06/27	10:31:09	0011	79.950	80.830	112	01	0.03034	0011
COMPLETE	06/27	10:31:22	0011	80.060	80.810	114	04	0.04488	0012
REJECT	06/27	10:31:49	0011	79.720	81.060	122	02	0.00000	0013
COMPLETE	06/27	10:32:07	0011	80.240	80.820	112	02	0.03662	0014
COMPLETE	06/27	10:32:24	0011	79.940	80.860	118	02	0.03404	0015
COMPLETE	06/27	10:32:41	0011	80.860	80.860	117	00	0.00000	0016
COMPLETE	06/27	10:32:55	0011	79.730	80.830	113	03	0.03676	0017
COMPLETE	06/27	10:33:17	0011	79.460	80.850	124	02	0.03237	0018
REJECT	06/27	10:33:35	0011	79.550	81.050	122	01	0.00000	0019
COMPLETE	06/27	10:33:48	0011	80.020	80.820	119	01	0.03075	0020
REJECT	06/27	10:34:02	0011	80.110	81.000	116	01	0.00000	0021
COMPLETE	06/27	10:34:16	0011	80.200	80.760	119	02	0.04104	0022
REJECT	06/27	10:34:37	0011	80.150	80.950	116	02	0.00000	0023
COMPLETE	06/27	10:34:56	0011	79.840	80.820	120	02	0.03263	0024
COMPLETE	06/27	10:35:17	0011	79.750	80.870	115	02	0.03209	0025

ACCEPTANCE TEST DATA
AUTOMATIC REGULATION

	Date	Time	Unit#	Initial F	Final F	Amplitude	#passes	Kcon	Run#
COMPLETE	06/27	10:41:42	0012	78.600	80.950	123	02	0.03187	0001
REJECT	06/27	10:42:02	0012	78.380	80.990	121	02	0.00000	0002
COMPLETE	06/27	10:42:20	0012	78.840	80.800	120	02	0.03494	0003
COMPLETE	06/27	10:42:38	0012	79.220	80.900	119	02	0.03497	0004
COMPLETE	06/27	10:42:58	0012	78.760	80.790	119	02	0.03842	0005
COMPLETE	06/27	10:43:17	0012	78.500	80.870	122	03	0.03438	0006
REJECT	06/27	10:43:40	0012	0.000	0.000	023	00	0.00000	0037
COMPLETE	06/27	10:44:21	0012	78.410	80.810	120	03	0.04055	0008
COMPLETE	06/27	10:44:44	0012	78.960	80.770	119	02	0.03444	0009
COMPLETE	06/27	10:45:03	0012	78.230	80.830	120	02	0.03738	0010
COMPLETE	06/27	10:45:21	0012	77.450	80.850	118	02	0.03635	0011
COMPLETE	06/27	10:45:40	0012	78.790	80.900	119	02	0.03739	0012
COMPLETE	06/27	10:45:57	0012	78.850	80.770	122	02	0.03522	0013
REJECT	06/27	10:46:15	0012	78.380	81.170	117	02	0.00000	0014
REJECT	06/27	10:46:34	0012	78.430	81.100	119	02	0.00000	0015
REJECT	06/27	10:46:56	0012	78.750	80.990	121	02	0.00000	0016
COMPLETE	06/27	10:47:13	0012	80.030	80.880	117	02	0.03261	0017
REJECT	06/27	10:47:32	0012	79.230	81.030	114	02	0.00000	0018
COMPLETE	06/27	10:47:51	0012	78.550	80.860	114	02	0.03208	0019
COMPLETE	06/27	10:48:38	0012	79.180	80.860	117	03	0.03469	0020
COMPLETE	06/27	10:49:41	0012	78.770	80.770	122	02	0.03456	0021
COMPLETE	06/27	10:50:34	0012	80.560	80.790	123	01	0.02191	0022
COMPLETE	06/27	10:50:54	0012	79.330	80.760	122	02	0.03634	0023
COMPLETE	06/27	10:51:24	0012	78.770	80.790	110	02	0.03359	0024
COMPLETE	06/27	10:51:52	0012	78.770	80.790	120	03	0.03665	0025

APPENDIX IV

ACCEPT/REJECT SUMMARY

AUTOMATIC REGULATION

BULOVA SYSTEMS & INSTRUMENTS CORPORATION

APPENDIX IV

Accept/Reject Summary

Automatic Regulation

Reliability	Shoot No.	Reason for Rejection: Low Ampl.	Beat Rate Overshoot	Non-Start	Beat Rate High at Start	No. of Welds	Avg. No. of Welds
19/25	1	2	2	1	1	68	2.7
23/25	2	-	2	-	-	81	3.2
21/25	3	2	4	-	-	76	3.0
11/25	4	1	10	-	1	64	2.6
20/25	5	-	3	1	1	68	2.7
22/25	6	1	2	-	-	69	3.0
21/25	7	1	2	-	1	74	3.0
19/25	8	2	2	2	-	73	2.9
17/25	9	-	8	-	-	72	2.9
19/25	10	1	4	1	-	76	3.0
Total 192/250		10	39	5	4	721/250	2.9

APPENDIX V

HUMAN FACTORS ENGINEERING

APPENDIX V

Human Factors Engineering

The Automatic Regulation Machine and the Automatic Poising Machine have been designed in accordance with the applicable criteria of MIL-H-46855A "Human Engineering Requirements for Military Systems, Equipment and Facilities".

The machines will be operated inside modern heated and air-conditioned buildings. The housings have been designed to shield and protect the mechanisms against dirt, moisture and accidental physical damage. The housings also were designed to protect the operator and others from harm. Provision has been made for panel interlock switches to prevent the accidental emission of radiation, in accordance with OSHA requirements.

The Machines are intended to be operated in a manufacturing environment with appropriate illumination, ambient temperatures and noise ordinarily encountered in such locations. The work areas are situated at a height which permits operation while seated, with kneeroom and kickspace provided. Workspaces, for in-process material, are provided. There are a minimum of controls and indicators for the operator to be concerned with, and no unusual force or direction of movement is required. Controls are labeled, indicator lights are red and green, for "go" and "no go" conditions. Controls are so placed that accidental operation is precluded.

DATE

ILME

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